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Debris Slides and Related Flood Effects in the 4-5 August 1938 Webb Mountain Cloudburst: Some Past and Present Environmental Geomorphic Implications

Carl A. Koch
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Carl A. Koch entitled "Debris Slides and Related Flood Effects in the 4-5 August 1938 Webb Mountain Cloudburst: Some Past and Present Environmental Geomorphic Implications." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

G. M. Clark, Major Professor

We have read this thesis and recommend its acceptance:

Don W. Byerly, Garrett Briggs

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Chancellor
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DEBRIS SLIDES AND RELATED FLOOD EFFECTS IN THE 4-5 AUGUST 1938 WEBB MOUNTAIN CLOUDBURST: SOME PAST AND PRESENT ENVIRONMENTAL GEOMORPHIC IMPLICATIONS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Carl A. Koch

December 1974

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ABSTRACT

On the night of 4-5 August, 1938 a cloudburst occurred over Webb Mountain, Tennessee, that lasted three hours with a rainfall in excess of twelve inches. This sudden deluge caused considerable debris sliding and flooding which resulted in the loss of eight lives and extensive property damage in the narrow valleys below the slide area. Over 100 individual slide scars were identified in the study area, 40 of which occurred in the Matthew Creek watershed.

The debris slide movement is thought to have been initiated by sliding at the head of the scar, with the mass of moving rock, soil and forest debris remaining intact and then developing into a debris flow as it progressed downslope. The major volume of material was carried out of the upper stream channels and slide tracks and deposited in the lower reaches of the streams.

Intense summer rainstorms are the major cause of debris slides in the Appalachian Highlands south of the glacial border. Complex cultural and physical factors interact to affect an individual slide location. Precipitation is a critical localizing factor, as well as the rate of water infiltration which increases the soil pore pressure very rapidly during intense rainfall, such that soil and regolith fail by sudden reduction in their shearing strength.

Careful field investigation was the method of obtaining detailed data on the slide areas. All slides were plotted on a large map of the entire area. The Matthew Creek slide area was the center of detailed study.

Evaluation of several types of imagery indicated the Ekatachrome Infrared Aero film to be the most useful. The look angle, altitude and vegetational foliage are important factors in defining the slide scars with aerial photography.

The accumulation of data over longer time intervals will improve recurrence interval projections. Further debris slide studies will add to the understanding of slide localization and distribution factors and areas of slide potential can better be determined.

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CHAPTER I

INTRODUCTION

I. STATEMENT OF THE PROBLEM

On the night of 4-5 August, 1938, a series of rainstorms of great intensity passed over the mountainous portion of Sevier County, Tennessee. The most severe cloudburst occurred along the east end of Webb Mountain (Figure 1 and Plate 1).

The downpour lasted about four hours and the maximum rainfall was estimated to be in excess of twelve inches (Moneymaker, 1938). Conversations with local residents and examination of historical records indicate that a storm of this intensity did not occur 30 to 40 years prior to 1938, nor have any cloudbursts of unusual proportions been noted from 1938 to the present in the Webb Mountain area.

The flash flooding and debris slides which occurred during the downpour resulted in the death of eight people and extensive property damage (T.V.A. Hydraulic Data Report, 1958).

One purpose of this thesis is to investigate several debris slides in a single slide area. The investigation is centered around a study of the nature of post-storm changes. Soil samples and measurements of the debris slides were taken to develop this examination of time - space relationships in an area of landslides. A second purpose was to use several types of remote sensing techniques to evaluate which methods would be most useful in detecting old slide scars. These media were also used to map the debris slide scars and flow tracks.

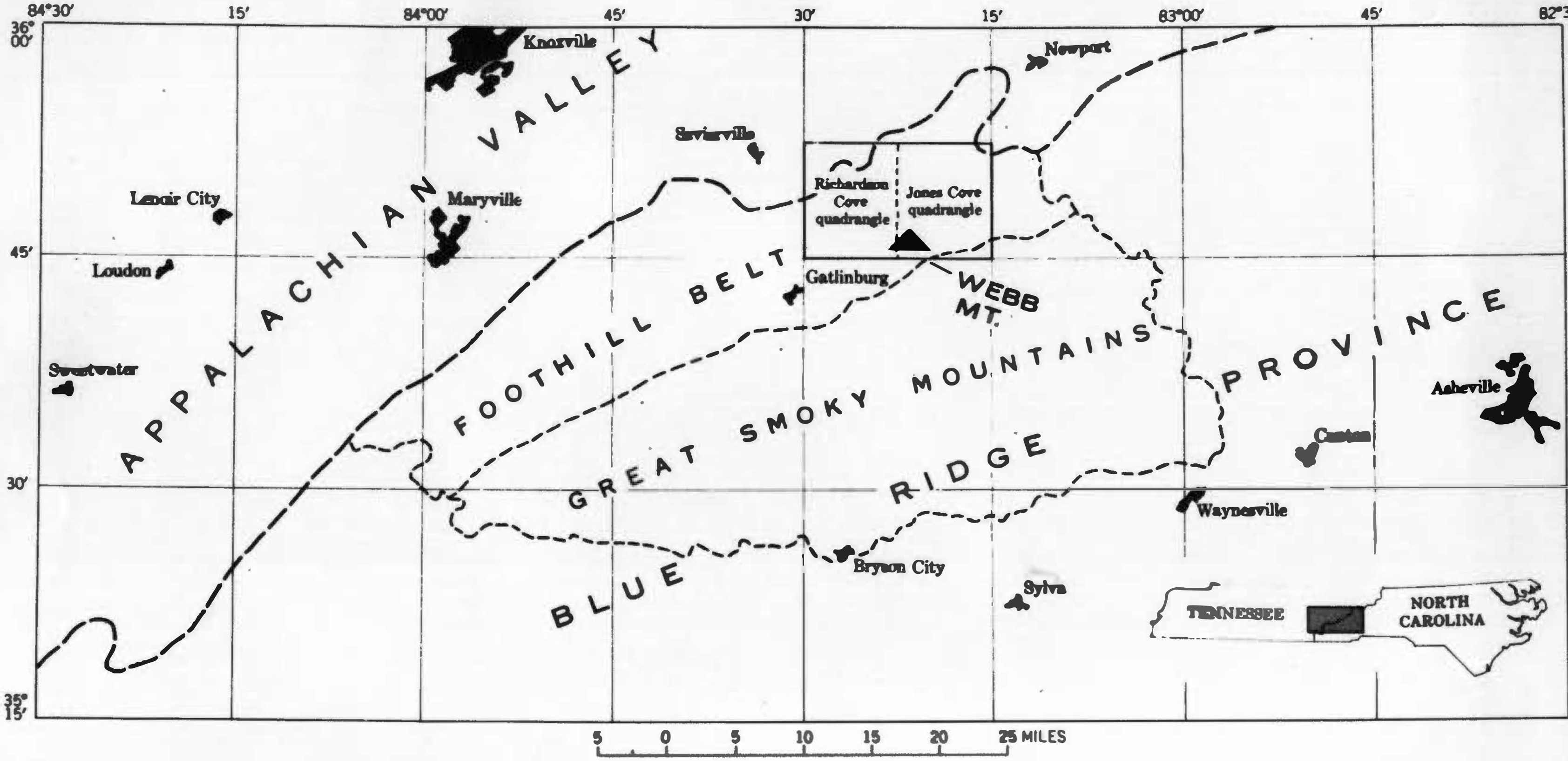

Figure 1. Map of Great Smoky Mountains region, Tennessee and North Carolina. Webb Mountain is a 5 mile (8Km) east-west trending ridge located near the southern boundary of Richardson Cove and Jones Cove quadrangles.

Source: Warren Hamilton, 1961, Geological Survey Professional Paper 349-A, p. A-2.

II. DATA COLLECTION AND ANALYSIS

Data were collected by the examination of historical records, through field records, and by the use of airborne imagery and personal interviews.

Historical Records

There is an abundance of old ground and aerial photographs, maps, written reports and personal communication available for the Webb Mountain area. The primary source of this historical material is the Tennessee Valley Authority. The T.V.A. Hydraulic Data Branch report 976-1938 contains the accounts of several field investigations. Included in this report are several newspaper accounts, and photographs of the Webb Mountain debris slides, taken within a day after the storm.

A paper on the slides and storm of Webb Mountain was published by Moneymaker (1939). This paper discusses the erosion and transportion of material as a result of the cloudburst of 5 August, 1938. The report also contains several excellent photographs of the debris slides and flow tracks taken shortly after the storm.

Many old photographs were obtained from these reports. These photographs were compared to photographs taken during recent field investigations. These pictures show the changes that have taken place in the slide area since the 1938 storm.

Field Research Data

The Webb Mountain site was selected because of the availability of historical records which makes it possible to locate the old debris slide scars and flow tracks and to observe the changes in the slide areas as they became modified through time.

The debris slides were first located using T.V.A. aerial photographs taken of the slide area a few days after the 1938 cloudburst. The location of the scars was then confirmed by visiting the site of each debris slide on the ground.

Soil pits were dug in the slide scars and on slopes in the slide areas. Soil profiles were observed and a record was made of the thickness of the soil covering the old scars and undamaged slopes. Several soil samples were taken from these pits and used to determine post slide regolith changes, and for X-ray analysis to determine the most common clay minerals present.

Other field data include slide scar measurements such as slope angles and compass orientation. Vegetation samples were taken in and around the slide areas to study associations and revegetation of the scarred slopes.

Geological mapping of the Webb Mountain area was done on a reconnaissance basis by Hamilton (1961). Today there are four places in the slide areas where bedrock is exposed; rocks exposed fit the lithologic descriptions of the rocks of Webb Mountain given by Hamilton (1961, pp. 13-18).

Airborne Imagery

Black and white aerial photographs were used to obtain up-to-date coverage of the slide areas. Recent aerial photographs were compared to older ones taken of the debris slides over the years. This comparison shows in general the ground conditions that have existed in the area since the debris slides occurred in 1938.

U.S.G.S. and T.V.A. aerial photographs, taken in 1938 of Webb Mountain, were used to locate the debris slide scars and to plot the location of these slides on a mylar overlay map of the mountain.

In addition to the black and white imagery, the area has been covered by aerial photographs of different emulsion-filter combinations and thermal imagery. It was hoped that this type of imagery would define the old debris slide scars more definitively than pancromatic, "minus-blue" conventional aerial photography.

CHAPTER II

THE STUDY AREA

I. LOCATION

The area covered by this study lies within the Blue Ridge Province of the Appalachian Highland Division (Fenneman, 1938). The Blue Ridge Province includes the Great Smoky Mountains and the Foothill Belt in east Tennessee (Figure 1, page 2). The Webb Mountain area is restricted to the Foothill Belt in the southeastern portion of Sevier County, Tennessee.

Webb Mountain is included in the Richardson Cove and Jones Cove quadrangles (7-1/2 minute T.V.A.). The mountain covers an area approximately 5 square miles just north of the Great Smoky Mountains, bounded by the Little Pigeon River in the west and Dunn Creek in the east.

II. RELIEF AND DRAINAGE

Webb Mountain, located in the highly dissected foothills belt of the Great Smoky MOuntains, is characterized by steep slopes and narrow ridges and valleys. Slopes are predominantly 25 to 50 percent (24°42' to 40°), but range from 12 to 80 percent (16°10' to 38°40') (Powers, 1945). Maximum relief within the Jones Cove and Richardson Cove quadrangles is 2280 feet (691m). The lowest point is approximately 920 feet (279m) in the northwestern corner. The highest point, 3200 feet (933m), is in the southeastern corner of the area (Hamilton, 1961).

Within the Great Smoky Mountains National Partk south of Webb Mountain, peaks exceed 6000 feet (1818m).

In general, Webb Mountain consists of a single steep ridge, striking east-west, a little over 5 miles (8Km) long. It rises to an elevation of 3080 feet (933m) above sea level. The crest of the mountain stands about 1600 feet (485m) above the main valley floors (Plant 1).

The drainage system that has developed in the study area consists of steep sided parallel valleys, which have formed a vague dentritic pattern (Figure 2). The larger streams in the valleys below the flanks of the mountain follow the general east-west strike of the bedrock. The two major streams which drain Webb Mountain are Dunn Creek in the north and Webb Creek in the south. These two streams flow west to the Little Pigeon River. This river is the largest in the area and flows northwest across the strike of the topography and underlying rocks.

III. BEDROCK GEOLOGY

There have been few geological studies of any detail of the Webb Mountain area. Early geologic mapping of the Foothills Belt, which includes the thesis area, was done by Keith (1904) as part of a study of the southern Appalachians for the U.S. Geological Survey. A report by Moneymaker (1938) includes a brief description of the Webb Mountain rocks. Several other reports which generally consider Webb Mountain bedrock geology are summarized by King, Hadley, Neuman, and Hamilton (1958). A detailed geological study which describes the area just north

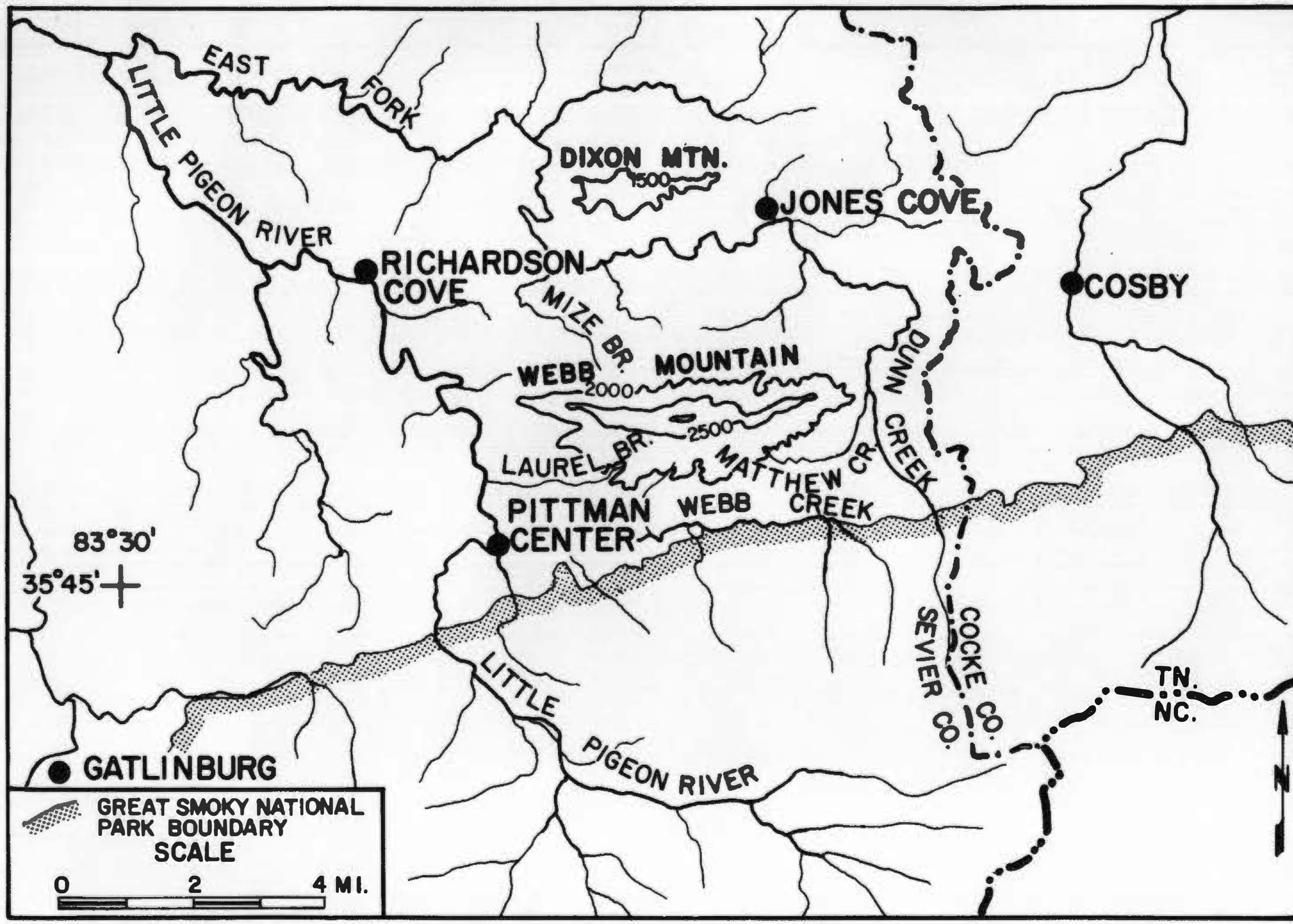

Figure 2. General drainage map of the Webb Mountain area.

of Webb Mountain was done by Brower (1973) of the Dixion Mountain mines. The most comprehensive geological study which includes the geology of Webb Mountain is a report by Hamilton (1961). A general description of the rock units of the thesis area given by Hamilton (1961) is summarized below.

The rocks of the Foothills Belt within the immediate area of Webb Mountain are all of sedimentary origin and are of late Precambrian, and Cambrian age. The bedrock in the area of study belongs to two major groups of different character, deposited in diverse sedimentary environments, brought to their present relative positions along thrust faults. One group is the Snowbird of the upper Precambrian Ocoee Series. The other group is the Walden Creek of the Ocoee Series also of Precambrian age, but stratigraphically higher than the Snowbird.

The Snowbird and Walden Creek Groups are separated by faults throughout the study area. Field investigation indicates that the structure of Webb Mountain is complicated. Northeast strikes and steep southeast dips generally prevail.

The Snowbird Group is dominated by a thick mass of metasiltstone, and the Walden Creek Group is a complex assemblage of shale and sandstone (Hamilton, 1961). Webb Mountain is surrounded by the Pigeon Siltstone and is in contact with no other formation. The Mountain has two conspicuous lithologic divisions (field investigation and Hamilton, 1961). The lower division is about 1000 feet thick and consists of thin-bedded sandstone, metasiltstone, and slate. The upper division is about 3000 feet thick, and consists of slate and sandstone, the latter mostly coarse and in thick graded beds (Appendix A). According to Hamilton (1961), the southern contact is conformable with the underlying Pigeon Siltstone and the northern contact is at least in part a fault contact. Because of the doubtful relation of the Webb Mountain rocks to other rocks in the area, they are not given a formal name by Hamilton (1961) (Table I).

The field observations made by this writer revealed few outcrops. Most of the bedrock is covered by very weathered colluvial boulders. The few outcrops that were discovered were located in the heads of debris slide scars. The lack of bedrock exposure, structural complexity, and lithologic similarities cause uncertainty in interpretation of the geology in the study area. Recent construction on the south side of Webb Mountain has exposed much of the lower unit rocks. A detailed study of these recently exposed rocks may lead to a greater understanding of the geology of Webb Mountain.

IV. CLIMATE

The extremes of relief in the study area creates a variety of as yet unstidued microclimates. Because of the lack of recording stations, the climate can only be described in generalities.

Due to topographic relief, the Webb Mountain area is subjected to a lowland humit temperate climate with hot summers in the lower elevations, whereas, the mountain area experiences a humid temperate climate with cool summers (Trewartha, 1954). According to Shanks (1954), the higher elevations of the Great Smoky Mountains south of the Webb Mountai 1 area possess a cool-temperate rain forest climate.

TABLE I

STRATIGRAPHIC UNITS OF OCOEE SERIES IN THE GREAT SMOKY MOUNTAINS

[Units marked with an asterisk occur in Richardson Cove and Jones Cove quadrangles. After King, Hadley, Neuman, and Hamilton (1958, table 1)]

Age		North of and below Greenbrier fault				South of and above Greenbrier fault	
Cambrian and Cambrian(?)		Chilhowee group	*Cochran formation and higher units Disconformity?		Correlation between these sequences not established	Rocks of Murphy marble belt	Nantahala slate and higher units (Precambrian(?) and early Paleozoic (?)) Lithologic break, but probably conformable
Later Precambrian	Ocoee series	Walden Creek group [1]	*Sandsuck formation *Wilhite formation [2] {Yellow Breeches member [1], Dixon Mountain member [1]} *Shields formation [1] *Licklog formation [1] Fault contact, sequence uncertain			Great Smoky group	Unnamed higher strata Anakeesta formation [1] Thunderhead sandstone [1] Elkmont sandstone [1]
			Western Great Smokies	Eastern Great Smokies			
		Unclassified formations.	Cades sandstone [2]	*Rocks of Webb Mountain and Big Ridge Rich Butt [1] sandstone			
		Snowbird group	Metcalf phyllite [1]	*Pigeon siltstone [2] *Roaring Fork sandstone [1] Longarm quartzite [1] Wading Branch formation [1]		Snowbird group	Roaring Fork sandstone [1] Longarm quartzite [1] Wading Branch formation [1]
		Base not exposed		Unconformity			Unconformity
Earlier Precambrian				Granitic and gneissic rocks			Granitic and gneissic rocks

[1] New stratigraphic name.
[2] Old stratigraphic name, with major redefinition.

Source: Warren Hamilton, "Geology of the Richardson Cove and Jones Cove Quadrangles Tennessee," Geological Survey Professional Paper, 349-A (Washington: Government Printing Office, 1961), p. A-5.

Although temperature records are not available for Webb Mountain, it might be included in Trewartha's (1954) classifications of the humid mesothermal climate of the southeastern United States. This places the coldest month between 32°F and 64.4°F and the warmest month above 50°F. These temperatures vary with elevations. According to Shanks (1945), temperatures in the Smoky Mountain area decrease an average of 2.23°F for each 1000 feet increase in elevation. The only known records of temperature data from a site near enough to the study area which might reflect the temperatures of Webb Mountain are from the Gatlinburg, Tennessee station (Table II).

Atmospheric precipitation in the immediate area of Webb Mountain has been recorded at the Jones Cove and Pittman Center stations (Table II). However, these stations are located near the base of the mountain (Plate 1) and may not reflect the amount of rainfall at the higher elevations. A dissertation by Bogucki (1970) and a report by T.V.A. (1938) indicate that in the Great Smoky Mountain area there is an increase in rainfall with increasing altitude. This effect of altitude on rainfall may also be true in the Webb Mountain area if similar conditions exist.

Intense local rainfall due to thunderstorms occurs mostly in the warm months of June through August. Severe local storms during the summer months commonly cause flash flooding in the narrow valleys of the study area (T.V.A., 1958).

TABLE II

ANNUAL TEMPERATURE DATA FOR GATLINBURG[b]

Month	Average Temperature, °F[a]
December	40.6
January	39.7
February	41.4
Winter	40.5
March	48.5
April	57.2
May	64.7
Spring	56.8
June	72.4
July	74.4
August	73.5
Summer	73.4
September	69.1
October	58.2
November	47.3
Fall	58.2
Year	57.2

[a]Average temperature based on a 29-year record, 1925-53. Source: U.S.D.A. Soil Survey of Sevier County, 1958.

[b]Station elevation 1,400 feet.

V. SOILS

The major soil type in the Webb Mountain area is developed on steep, highly dissected slopes where the depth to bedrock is seldom more than three feet. The thin soil mantle contains numerous rock fragments derived from the underlying parent material. This soil has been assigned to the Ramsey series by the Soil Survey of Sevier County, Tennessee (1956). The Ramsey series is described as:

> . . . soils developed on mountain slopes and ridge crests from the residuum of quartzite, sandstone and conglomerate, or slate and fine-grained conglomerate. In general the slate and fine-grained conglomerate give rise to the shaly silt loam type of the series and the quartzite, sandstone, and conglomerate give rise to the stony fine sand loam type.
>
> Ramsey soils are light brown, yellowish brown, brownish yellow or yellowish gray throughout or have pale-brown to light yellowish brown surface soils and brownish-yellow to pale-yellow subsoils. They are chiefly on steep slopes and have shallow, weakly developed profile layers. They vary considerably in depth and in degree of distinction between profile layers.

Two minor soil types that occur in the study area are derived from local colluvium or alluvium wasted and washed down from the steep slopes. These soils form at the base of the slopes and spread along the valley floors. The Soil Survey of Sevier County, Tennessee (1956) classifies these soils as the Barbourville and Jefferson soil series. These soils are described in the following way:

> . . . The parent materials are sandstone, quartzite, shale and slate washed from the Ramsey soils. The soils contain varying amounts of gravel or cobbles. They occur along small drainageways at the base of upland slopes, and on small sloping alluvial-colluvial fans where the small streams have washed the deposite along the valley bottoms.
>
> The Jefferson soils have yellowish-gray surface soils and brownish-yellor or yellow subsoils. The Barbourville soils differ from the Jefferson soils in not having distinct surface soil and subsoil layers. The Barbourville soils are brown and well drained.

VI. VEGETATION

The vegetation of Webb Mountain ranges from temperate deciduous forests at the lower elevations to coniferous forests at the higher elevations. The vegetation pattern of the mountain could be classified as an eastern forest system according to Whittaker (1956). Species diversity decreases from low elevations to high. Tree-species diversity is maximal in the cove forest transition of lower elevations and decreases toward the higher elevations (Whittaker, 1956).

Differences in soil moisture and exposure and associated elevation have influenced the vegetation types of Webb Mountain. There is a broad correlation between soil types and forest types. The Ramsey-Barbourville-Jefferson soil associations on the rough mountainous land of the study area may be considered together.

According to the Soil Survey of Sevier County Tennessee (1956) in the above mentioned soil associations, elevation and exposure are the primary factors determining the forest type. The yellow pine-hardwoods forest type in which Virginia pine is dominant, prevails at lower elevations. The hardwoods include such species as white, chesnut; scarlet, southern red, black, and blackjack oaks; white pignut; shagbark hickories, red maple, and blackgum. At elevations above 2000 feet the land consists largely of pine. The dominant pine is pitch pine with some table-mountain included. This forest type is a serious fire hazard as it occupies dry sites along the ridge crests. There have been two small fires since 1938: one on the east end of the mountain, and another in the central portion near the crest (personal communication with local residents). The blackened stumps of trees are still visible at these forest fire sites.

A variation of the upland hardwood forest type is the cove hardwoods (Whittaker, 1956) which occur in coves and on the cool moist slopes of Webb Mountain. Characteristic species (Soil Survey Sevier County, Tennessee, 1956) include yellow-poplar, basswood, hemlock, birch maple, magnolia, hickory, oak and ash. Mountain laurel and rhododenron from dense thickets in the valley bottoms are the principal shrubs in the undergrowth.

VII. SETTLEMENT AND ECONOMY

Webb Mountain was settled a century or more after the initial opening of the region (Pearsall, 1959). The area now stands as an illustration of the persistence of a frontier economy of patch farming and hunting on land that can no longer support these occupations. These primitive farms are confined to the narrow valleys and steep hills around the base of the mountain. The general standard of living is extremely low.

The principal crops are corn, beans, tobacco, potatoes, and a variety of garden vegetables. Steeply-sloping worn out fields can no longer support the residents of the mountain and the population has decreased considerably since 1956 (Pearsall, 1959), until only a few families live in the area today.

Lumber and pulpwood have been harvested in small-scale operations on Webb Mountain (personal conversations with residents). All of the original forest has been cut over at least once. The cutting has gone on for more than a century under the frontier system of clearing new lands as old ones lost their fertility. Lumbermen in the latter part of the nineteenth and early twentieth century continued to remove the original forest cover (Pearsall, 1959). All of the present forest is at least second growth vegetation.

In the last few years the natural features have attracted tourist projects. The construction of weekend cabins and summer homes have developed on much of the lower portion of the South slope of Webb Mountain.

CHAPTER III

MASS MOVEMENT

I. INTRODUCTION

Gravity transport of debris on slopes constantly modifies the landscape. As man expands his activities to regions of steep slopes, the understanding of the processes of gravity-induced erosion becomes increasingly more important.

II. CLASSIFICATION

In general, the methods of mass movement downslope are classified on the basis of three features. Birot (1968) defined these features as: the speed of movement, the degree of coherence on the debris being moved, and whether the debris is carried along by an agent or simply moves under the influence of gravity.

Young (1972) bases his classification on the following properties: type of material, type of movement, and rate of movement. These most recent classifications have evolved mainly from the works of Heim (1882, 1932), Sharp (1938), Ward (1945), Varnes (1958), and Hutchinson (1968). Two of the most commonly cited classifications are shown in Table III (Sharp, 1938) and Table IV (Varnes, 1958).

III. TERMINOLOGY

The terms concerning mass movement used in this study are taken

TABLE III

MASS MOVEMENT CLASSIFICATION BY C. F. STEWART SHARPE

I. Slow Flowage - usually imperceptible

  Creep

    Soil Creep

    Talus Creep

    Rock Creep

    Rock-Glacier Creep

  Solifuction

II. Rapid Flowage - relatively wet

    Earth flow

    Mudflow

    Debris Avalanche

III. Landslide - relatively dry

    Slump

    Debris Slide

    Debris Fall

    Rockslide

    Rockfall

IV. Subsidence - surface material displaced vertically downward

---

Source: C. F. Stewart Sharpe, <u>Landslides and Related Phenomena</u> (New York: Columbia University Press, 1938).

TABLE IV

MASS MOVEMENT CLASSIFICATION BY DAVID J. VARNES

- I. Falls
  - Bedrock
    - Rockfall
  - Soils
    - Soilfall
- II. Slides
  - Bedrock
    - Few Units
      - Rotational Slump
      - Planar Glide
    - Many Units
      - Rockslide
  - Soils
    - Planar Block Glide
    - Rotational Block Slump
    - Debris Slide
    - Failure by Lateral Spreading
- III. Flows
  - All Unconsolidated Material
    - Dry
      - Rock Fragment Flow
      - Sand Run
      - Loess Flow
      - Rapid Earth Flow
      - Debris Avalanche
      - Slow Earth Flow
    - Wet
      - Sand or Silt Flow
      - Debris Flow
      - Mud Flow
- IV. Complex
  - Combinations of Material or Type of Movement

Source: David J. Varnes, "Landslide Types and Processes," Landslides in Engineering Practice, Highway Research Board Special Report 29, E. B. Eckel, editor (Washington: Highway Research Board, 1958).

from Clark (1973). These terms agree with the field observations of this writer and are stated below:

> . . . A varied group of terms and definitions utilized by many writers has evolved to describe the processes and landforms studied in the research. One major goal of the work was to gather field data on the nature of this class of mass movements. With the information gained, some tentative inferences can be made concerning the processes involved in material erosion, transport and deposition. The author now suggests that a preference may be given to terminology that most closely describes the inferred complex processes. Accordingly, the following terms are defined below and certain of them are schematically illustrated in Figure 3.
>
> Chute - A general term for hillslope areas where vegetation and soil mantle have been partially or completely removed by the processes of debris slided/debris flows. Chutes often extend from short distances below ridge crests downslope to debris fans or to channelways if fans are absent. (See Hack and Goodlett, 1960, pp. 43-44).
>
> Water Blowout - Erosional holes in hillslope debris mantle that show no evidence of ground cover breaks above or below the depression. (See Hack and Goodlett, 1960, pp. 45-47).
>
> Debris Fan - Fan or cone-shaped accumulations of predominantly water laid debris, mainly stones and gravel, some fines, and vegetational remains. Debris fans are the depositional termini of chutes in locations where chutes do not directly enter channelways; some debris fans, however, may be transitional to high-energy alluvial fans. (See Hack and Goodlet, 1960, p. 53).
>
> Debris Slides - Rapid mass movements initiating along one to many regular to irregular, surfaces of discrete movement that primarily involve soil and vegetation but occasionally also upper bedrock layers. Initial movement may be rotational or translational in nature, or may involve elements of both. Multiple occurrences within the study region were related to intense precipitation events on relatively steep slopes possessing a soil mantle. (See Rapp, 1963, pp. 196-197).
>
> Slide Scar - The erosional depressions produced on hillslopes by debris slide activity. Slide scars are often transitional downslope to flow tracks.
>
> Debris Flows - Rapid mass movements involving rapid debris flowage, containing coarse-grained materials, and resulting almost invariably from intense precipitation. (See American Geological Institute, 1973, pp. 181-182).
>
> Flow Track - That portion of the chute modified by debris flow activity accompanied by fluvial erosion, transportation and deposition.

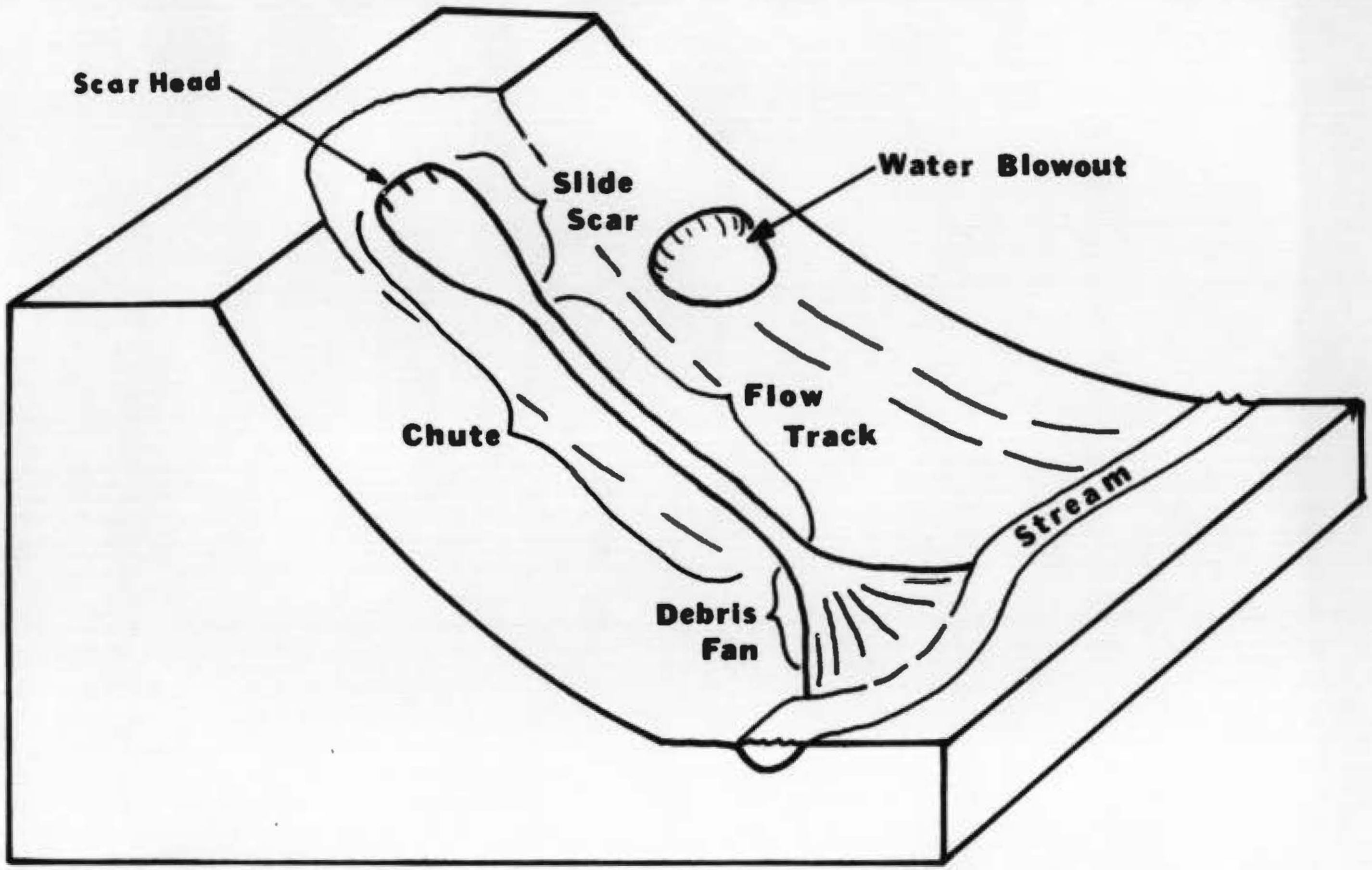

Figure 3. Schematic block diagram illustrating the terminology used for features produced by rapid mass movements.

Source: D. J. Bogucki, 1970, and G. M. Clark, 1973.

Log Jams - Large deposits predominantly composed of tree trunks that are commonly emplaced on the outsides of chute bends and on debris piles. (See Bogucki, 1970, p. 53).

Debris Piles - Accumulations of vegetational remains, especially stems and roots, soil and rock on the upslope sides of standing trees bordering chutes and downslope from water blowout. (See Hack and Goodlet, 1960, p. 45 and Figure 24, p. 46; of Debris Dams; see Bogucki, 1970, pp. 80-81).

Perhaps the major break with common usage in this research is the abandonment of the popular term Debris Avalanche in favor of the terms Debris Slide/Debris Flow. Although much remains to be known, especially from the rheological standpoint, of specific forces and the nature of movements, the field evidence accumulated in this work suggests that these terms better describe the gross mass movements involved in chute formation.

IV. DISTRIBUTION

Debris slide/debris flow is an important geomorphic phenomena in the formation of slopes and valleys. Debris slides/debris flows produced by storms are probably common events over the last 100 years in the Appalachians south of the glacial border (Figure 4). The evidence gathered in this study can probably be related to a wide area in the Appalachian Highlands. As more information is gathered, the effectiveness of debris slides/debris flow in the evolution of slopes and valleys will be revealed.

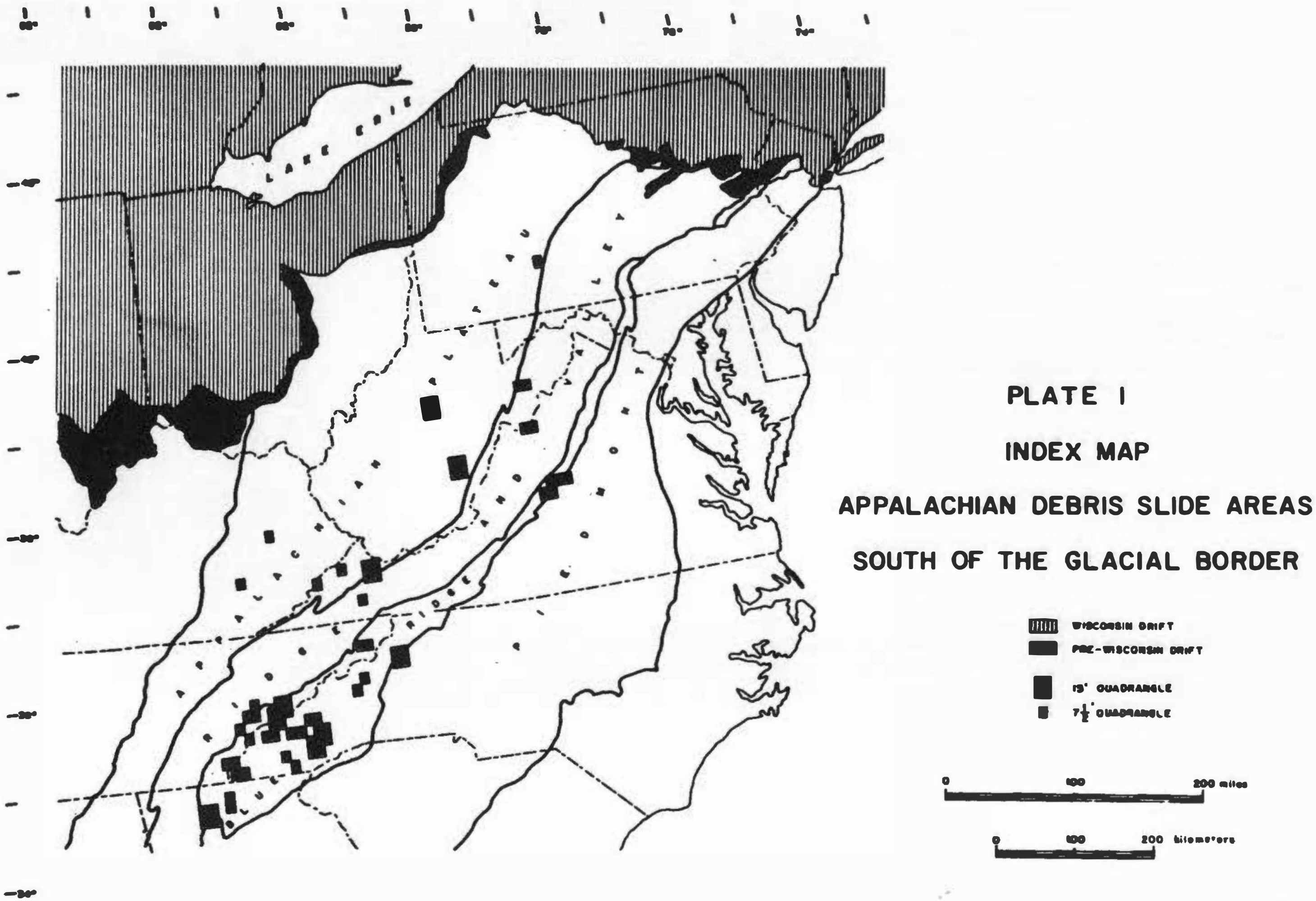

Figure 4. Index map, Appalachian debris slide areas south of the glacial border.

Source: R. H. Schneider, 1973, Plate 1.

CHAPTER IV

CLIMATOLOGICAL AND GEOMORPHIC EVENTS ON THE NIGHT OF 4-5 AUGUST 1938

I. INTRODUCTION

On the night of 4-5 August 1938, a severe cloudburst struck Webb Mountain, Sevier County, Tennessee. The study area was deluged by an average of 12 inches (30 cm) of rain in about four hours (T.V.A., 1938). The resulting debris slides and flooding killed eight people (T.V.A., 1958) and left fifty people destitute (Pearsall, 1959). In addition, many acres of timber and bottom land were permanently damaged.

II. THE STORM

One of a series of severe cloudbursts occurring along the North Carolina-Tennessee state line (T. V.A., 1938) fell along the crest of Webb Mountain. The cloudburst produced rainfall of an intensity and duration that is apparently rare in the Webb Mountain area. One resident of the area stated (T.V.A., 1938), that her great grandfather was one of the first settlers on Webb Mountain and that she had heard the older people discuss weather and floods many times, but she had never heard of a similar storm in the vicinity of the mountain.

Statements of residents of the study area (personal conversation and T.V.A., 1938) revealed that the storm occurred in two briefly separated parts. The first cloudburst came from the southwest and lasted about two hours. Then after about a five-minute lull a second storm came from the west and the rainfall resumed. The intense portion of the storm began about 11:30 P.M. on 4 August 1938 and lasted three hours until 2:30 A.M., 5 August 1938. The storm was accompanied by sheet lightening but only slight winds.

The storm covered about four square miles along the crest of Webb Mountain as evidenced by 1938 aerial photographs and personal field observations of the affected ridge. The writer believes that the greatest proportion of heavy rainfall was confined to the south slope of the mountain between the headwaters of Matthews Creek and Laurel Branch (Plate 1). In this area the debris slides are longer and more numerous. According to the T.V.A. report (1938), the Matthews Creek area had the greatest modification and runoff of any other stream headwaters on Webb Mountain.

Accurate data regarding the amount of rainfall were difficult to obtain. At the time of the storm, the nearest raingauge was station 242 in Cosby, about 2-1/2 miles (4Km) east of the study area. This station reported 1.13 inches (2.8cm) for the storm of the night of 4 August 1938 (T.V.A., 1938). Because of the absence of raingauges on Webb Mountain, a bucket survey method was used. According to the T.V.A. (1938) report of the storm, the source of catches were kettles and buckets left outside during the storm by the local population. At the storm center all the vessels left exposed were washed away or overturned by the flood of water. From the catches located and an inspection of the streams, the rainfall had been estimated to be in excess of 12 inches

(30.4cm) (T.V.A., 1938 and Moneymaker, 1939). The excessive precipitation fell along a narrow belt 1/2 to 3/4 miles (.8-1.2Km) in width and 2 miles (3.2Km) in length along the ridge crest in the Matthews Creek area (T.V.A., 1938).

III. THE FLOODS

During the storm, all the streams in the vicinity of Webb Mountain were affected by the intense rainfall. The streams within the storm center were changed from their normal trickle to raging torrents, which drained into the larger streams flowing out of the area causing them to flood.

According to Moneymaker (1939) most of the streams draining Webb Mountain were heavily swollen. The water in the headwaters near the crest was 15 feet (4.6m) deep in gullies sloping steeper than 30 degrees (58%). On many of the slopes , water moved down in sheets. The east fork of the Little Pigeon River, Dunn and Webb Creeks experienced a severe flood. The crest at Sevierville (Figure 1, page 2), ten miles northwest of Webb Mountain, reached a stage of 12.17 feet (3.8m) at the gauging station (T.V.A., 1938). Along Webb and Dunn Creeks many bridges and long sections of roads were washed away by the high waters.

Several streams affected by the cloudburst were investigated by the T.V.A. Hydraulic Data Division (T.V.A., 1938) after the storm, to obtain runoff computations (Table V). It was difficult to acquire accurate runoff data because of the irregular flow of the water and the rough condition of the channels. High water marks were indefinite due

TABLE V

DISCHARGE DATA FOR THE WEBB MOUNTAIN AREA
4-5 AUGUST, 1938

Location	Drainage Area Square Miles	C.F.S. at Peak Runoff	C.F.S. Per Sq. Mile
Lower Matthew Creek	2.4	-	746.5
Jones Branch	1.0	-	1732.5
Laurel Branch	1.8	4800.0	2700.0
Warden Branch	0.7	4300.0	6200.0
Mill Dam Branch	0.6	5000.0	8300.0
Webb Creek	17.7	6600.0	370.0

Source: Compiled from the Tennessee Valley Authority, H.D.-976, 1938.

to the spray and debris which were dashed above the actual water level (T.V.A., 1938). This writer believes that another reason for the difference in elevation of the water surface from one side of the stream to the other was probably caused by the water undulating from side to side as it rushed down the channel. According to T.V.A. (1938) most of the sections used for runoff computations were taken close to the mouths of the streams because of channel conditions, and because a reach of sufficient length was impossible to find farther up on the creeks.

The T.V.A. (1938) hydraulic data shown on Table V are not a very good indication of runoff on Matthews Creek because the water was able to spread over bottom lands and was ponded by drift dams before reaching the section measured. Upstream from the cross section, the flow was probably several times the rate shown. Jones Branch is a very good measurement of flow because of the straight, clean condition of the channel and that the flood was confined to the stream bed (T.V.A., 1938).

IV. SLIDE CHARACTERISTICS

Slope Gradients

The gradients in the major debris slide areas on Webb Mountain were measured in the field with a Brunton compass. The results appear in Table VI. In general, slides developed on slopes that ranged from 32 to 43 degrees. However, within any particular slide area, slopes adjacent to the scared slopes having the same steepness, did not develop debris slides. The general profile is S-shaped with gentle tops and bottoms and steep intermediate slopes (Hamilton, 1961).

TABLE VI

RANGE OF SLOPE STEEPNESS IN DEBRIS SLIDE AREAS OF WEBB MOUNTAIN

Slide Area	Degrees	Percent	Number of Recognizable Slides
1. Upper Matthew Creek	32-40	62.85	40
2. Upper Warden and Mill Dam Branch	34-40	67-84	15
3. Upper Laurel Branch	32-40	62-84	18
4. Upper Jones Branch	38-43	78-93	20
5. Upper Chucky Creek[a] opposite Warden Creek	38-42	78-90	8

[a]The branches of Chucky Creek are unnamed.

Distribution and Orientation

Most of the debris slides occurred near the crest of the mountain between 3300 feet (670m) and 3000 feet (814m) of elevation. Excepted from this range of elevation are three recognizable scars in Jones Branch between 1800 and 2000 feet (594 and 610m) where the slope was very steep.

The number of scars is much greater on the south slope (73 slides) of the mountain than on the north slope (28 slides). As shown in Table VI, the maximum number of debris slides occurred in the upper Matthews Creek area. The largest number of debris slides on the north slope occurred in the upper Jones Branch area. It should be noted that the number of slides in this area are much less than in the upper Matthews Creek area which lies opposite, on the south slope, separated by less than 1000 feet (304m).

The compass direction of recognizable debris slides was determined from aerial photographs and field observations (Table VII). Counts were made of the number of scars and the aspect of the hillsides for the four major compass directions in the manner described by Flaccus (1959). For example, any slide which faced up to 45 degrees to either side of a cardinal compass point was assigned to that point.

Most of the slopes on the south side of Webb Mountain faced between 45 degrees east and west of south. A visual inspection of aerial photographs and a topographical map indicates that the steepest slopes faced in a southeast direction. On the north side of the mountain, the main slope direction is between 45 degrees east and west

TABLE VII

ASPECT (FACING DIRECTION) OF SLOPES WITH SLIDES IN THE WEBB MOUNTAIN DEBRIS SLIDE AREA

Quadrant	Number of Slides: South Side of Mountain	Number of Slides: North Side of Mountain
North (N-45°-W to N-45°-E)	-	14
East (E-45°-N to E-45°-S)	15	12
South (S-45°-E to S-45°-W)	58	-
West (W-45°-S to W-45°-N)	-	2
Total	73	28

of north. An exception is the upper Jones Branch slide area where an equal number of slopes face between north 45 degrees east to due east.

General Description

Scars produced by debris slides with few exceptions are located in slight depressions at the heads of major valleys and tributary draws. A few scars developed on slopes where there was no evidence of any previously existing depressions (field observations and Moneymaker, 1939). The slides were of three distinct types according to T.V.A. (1938). Some small slides occurred within the soil mantle (Figure 5) where loosened material sloughed off as a fluid mass, and water continued to flow from the scar for several days. Another type of slide was formed along stream channels where the slopes were oversteepened by undercutting (Moneymaker, 1939). The third and largest type of slide occurred on the steep slopes near the crest of the mountain (Figure 6). These slides moved down the slopes as a flowing semi-fluid mixture of regolith and water, removing the vegetation and soil to expose the bedrock surface (Moneymaker, 1938 and T.V.A., 1938).

From field observations and inspection of aerial photographs of Webb Mountain, the writer believes that all but a few of the debris slides occurred in the upper rock units of Webb Mountain. As described by Hamilton (1961), the upper division rocks consist of thick-bedded course sandstone and interbedded metapelite. In the slide areas bedrock is rarely exposed, but there is an abundance of weathered boulders of course sandstone on the slopes. A few outcrops were found located in

Figure 5. A debris slide scar near the upper end of Matthews Creek. The slide was entirely within the soil mantle, a sloughing off of the saturated clayey soil (T.V.A., 1938).

Source: Tennessee Valley Authority, Hydraulic Data Branch Report 976-1938, photograph No. 5655E, taken on 8 August 1938.

the head of debris slide scars in the Matthew Creek slide area (Figure 6). The material exposed is a very weathered, medium grained sandstone in laminated platy beds, interbedded with a dark-gray, thin-bedded metapelite. Two recognizable slide scars in the lower part of the Jones Branch slide area were observed in the Pigeon metasiltstone which underlies the lower slopes of Webb Mountain.

The heads of the debris slide scars vary from rectangular to crescent shaped. The scars narrow slightly toward the mouth and become transitional down slope to form flow tracts. Many of the debris slide scars, regardless of their location and size, have multiple heads.

Some general observations about the dimensions of the slide scars were noted by the writer. Although the dimensions were not measured when the scars were fresh and clear of vegetation and soil, the dimensions are comparable to other studies of debris slide scars (Flaccus, 1959; Bogucki, 1970; Hack and Goodlett, 1960; Williams and Guy, 1973; Schneider, 1973).

The head of the debris slide scar is the steepest point of the longitudinal profile. The general shape of the long profile is slightly concave upward. The cross profile of the slide scar floor is concave, and this is also true of the slide track. The face of the slide scar heads range from 2 to 4 feet (.6 to 1.2m) above the floor of the slide. Downslope the slide track becomes narrower and deeper than at the scar head. The exact length of the slide scars was difficult to determine because of post-slide deposition and erosion of the scars. In addition, the slide scars were swept clear of the sliding materials and modified

Figure 6. Debris slides at the head of draw No. 3 (Plate 1) in the Matthew Creek Slide area. The vegetation and soil have been removed to expose the bedrock surface.

Source: Tennessee Valley Authority, Hydraulic Data Branch Report 976-1938, photograph No. 4480A, taken on 8 November 1938.

by gullying during the storm (Moneymaker, 1939), making it impossible in most cases to determine where the slide scar ends and the flow track begins. According to Schneider (1973), the average width of a debris slide scar head is greater than its length and this may be true of the debris slide scars of Webb Mountain. The width of the scars vary from less than 10 feet (3m) to greater than 80 feet (24m). The length of the scars range up to a few 100 feet (30m) in a downslope direction from their point of origin. However, many of the debris slide scars are shorter in their downslope direction than they are in width, or normal to the slope. According to Moneymaker (1939), the debris slide scars bear a close resemblance to the upper portions of large gullies.

The debris slides which stripped the regolith to the bedrock surface were probably initiated by the slip of a slump block. A slump block is defined as consisting of masses of regolith which have rotated as a coherent unit, moving downslope (Schneider, 1973). Scars were observed on trees, along the edge of slide tracks, 40 feet (12m) above the water line (T.V.A., 1938). The scars would indicate that some trees were carried along while standing erect, and that the mass of material removed from the hillside remained somewhat intact as it moved downslope. It appears that the slump block disintegrated as it continued to move, and subsequent movement developed an element of flow.

Flow Track, Erosion, and Deposition

This writer believes that erosion within the flow tracks occurred after the initial sliding. According to Moneymaker (1939), the debris slides took place during the first part of the storm, for the sliding materials and other direct evidence of it were swept away. Discussing the Matthews Creek slide area, T.V.A. (1938) states that the main channel had been lowered two or three feet (.6-.9m), and that the cutting occurred sometime after the peak discharge by the rock load and not by the water velocity (Figure 7). The erosion removed material mainly from the upper courses of channels down to where the gradient flattens. In the upper limits of the flow tracks, the channel is swept clean and deepened four or five feet (1.2-1.5m) into the bedrock (Moneymaker, 1939) (Figure 8).

In the lower reaches of the streams, water flowed six to eight feet (2-2.4m) deep over widths up to 500 feet (152m), where a stream one or two feet (.3-.6m) deep and four or five feet (1.2-1.5m) wide formerly flowed (T.V.A., 1938). In these bottoms, rock was deposited four to eight feet (1.2-2.4m) deep along with drift consisting mainly of large trees (T.V.A., 1938; Moneymaker, 1939). Boulder deposits of less than two feet (.6m) in diameter predominated (Moneymaker, 1939), but boulders up to five feet (1.5m) in diameter are common in the main channels (Figure 9). Most of the deposits are composed of materials eroded from previously formed deposits but some are composed nearly exclusively of newly eroded material (Moneymaker, 1939).

Water Blowouts

Water blowouts are features common to many areas of debris slides in the Appalachians. These features are defined by Hack and Goodlet (1960) as semicircular scars or erosional holes in the hillslope debris mantle that show no evidence of ground cover breaks above or below the

Figure 7. Erosion of a channel in the upper end of Matthew Creek, looking upstream. The channel is swept clean and deepened several feet to reveal the bedrock.

Source: Tennessee Valley Authority, Hydraulic Data Branch Report 976-1938, photograph No. 4480D, taken on 8 August 1938.

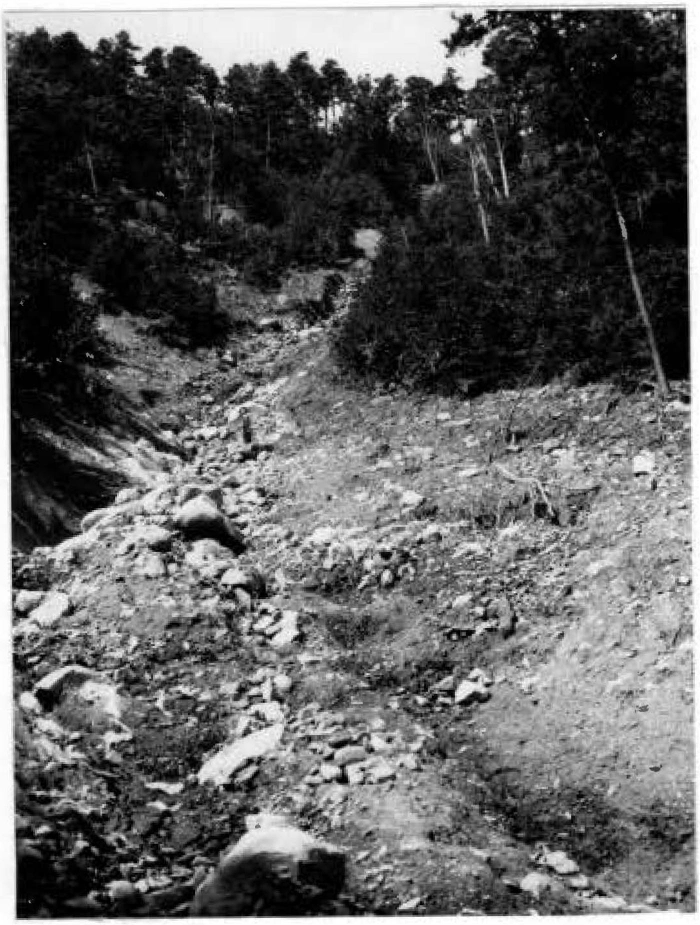

Figure 8. Boulder deposits in the main channel of draw 4 (Plate 1). View is looking up the draw toward debris slides near the crest of the mountain.

Source: Tennessee Valley Authority, Hydraulic Data Branch Report 976-1938, photograph No. 4478E, taken on 8 November 1938.

depression (Figure 2, page 8). Water blowouts form as the result of a concentration of hydrostatic pressure in the ground, and are probably locally controlled by the degree of weathering, fracture patterns, and compositional layering of the bedrock.

Groups of water blowouts are distributed at random in the Webb Mountain slide area and played only a small part in the modification of the slopes. The water blowout scars occurred in groups of two to three in line, along the same elevation. The size of the scars range in size from 10 to 20 feet (3-6m) wide and are three or four feet (.9-1.2m) deep. The depressions were probably deeper when the scars were fresh and not filled with soil and vegetation. One water blowout described by T.V.A. (1938) was 15 feet (4.5m) wide and five feet (1.5m) deep in the center, with most of the displaced material below the hole. The debris and water continued to flow down the slope leaving the surface only slightly disturbed.

In Figure 9, it can be seen that the center of the water blowout scar is below the downslope edge. The material removed would have to have been thrown out with some force to be lifted over the edge of the hole. The local people (personal conversation and T.V.A. interviews, 1938) reported that the land raised and waved and burst with a loud noise throwing soil and rock out with a great force. As shown in Figure 10, the water blowout removed the regolith to expose the bedrock, and in some cases water flowed from the holes for several days cutting a small gully below the depression (T.V.A., 1938).

Figure 9. A small water blowout along Webb Creek, above Pittman Center. It can be seen that the center of the scar is below the downslope edge.

Source: Tennessee Valley Authority, Hydraulic Data Branch Report 976-1938, photograph No. 4285D taken on 8 August 1938.

Figure 10. A large water blowout near the mouth of Jones Branch. The regolith has been thrown out to expose the bedrock.

Source: Tennessee Valley Authority, Hydraulic Data Branch Report 976-1938, photograph No. 5658C, taken on 8 September 1938.

CHAPTER V

POST SLIDE RECOVERY (AS OF 1974)

I. INTRODUCTION

The present landscape of Webb Mountain is principally the product of interaction between botanical and geomorphic processes. Over the intervening thirty-six years since the storm of 4-5 August 1938, the debris slide areas of Webb Mountain have been constantly modified. The processes of weathering, erosion, deposition and revegetation have continued to operate on the old slide scars and flow tracks. The decline of the local population and the subsequent abandonment of the destructive frontier type of farming has helped to restore stable conditions to some of the lower valleys.

II. SOILS

The Ramsey soil, as described in Chapter II, occupies all the areas of debris slides on Webb Mountain. This soild is classed as an azonal, Lithosol (Soil Survey, 1956). The Lithosols are a group of soils which lack pronounced horizons and consist of weathered masses of rock fragments. These soils occupy areas where runoff over steeply sloping land causes rapid erosion. The weathered material is removed from the surface before soil-forming processes can produce well defined horizons. Based on field observations, the lack of a well-developed soil profile in the Ramsey soils of Webb Mountain could be indicative of general slope instability.

Several soil pits were dug in the areas of major debris slides and their general location is shown on Plate 1. These pits were located in debris slide scars, adjacent to the scars and on slopes in the area of debris slides that remained stable. The pits in the slide scars are restricted to major scars which observed from aerial and ground (T.V.A., 1938) photographs, were stripped to bedrock. Soil profiles and depth were noted and these are described in detail in Appendix B. The soil clay minerals are discussed in Chapter VI.

The Ramsey Soil of the debris slide areas is low in organic matter, it is strongly acid (Soil Survey, 1956), and percolation is rapid through the thin soil mantle. Most of the drainage occurs as runoff over the steeply sloping survace which prevents the development of zonal soil-profile characteristics. Field observations have revealed that the rapid runoff and the resistance of the parent rocks to weathering are thw two major factors which affect the soil thickness. Partially weathered bedrock is usually less than 30 inches (76.2cm) below the soil surface.

From observation of the soil pits in the study area, the Ramsey Soil exhibits an A-C soil profile. The humus of the A-horizon is a few inches thick and grades downward immediately to a C-horizon of chips and blocks of weathered rock in a sandy to silty, clayey matrix. The average thickness of the soil is 28.5 inches (73cm), and varies little in thickness from slope to slope. No visual difference was noted in soil thickness between the slopes on which debris slides failed to develop, and slopes with slides.

The soil which has developed in the debris slide scars resembles the Ramsey Soil on the adjacent slopes, except the soil in the scars is much thinner and consists of a greater amount of partially weathered colluvial debris. The average thickness of the soil in the slide scars is seven inches (18 cm). The thickness of the humus developed in the scars averages 2.25 inches (5.6cm) as compared to 3.14 inches (7.8 cm) of humus on the adjacent slopes. The soil in the scars is formed mainly from colluvial veneer which has been shed into the depressions over the past thirty-six years. Little of the soil appears to have been developed from the decaying bedrock of the scar floor. Even though the soil that forms on the colluvium is thin, the humus layer is almost as well developed in the scars as on the surrounding slopes. This may be the result of the runoff being less rapid due to the large amount of forest little trapped in the concave depressions.

Erosion is very active in the scar heads. The face of the scars in most of the slide areas is exposed. The bare material is mainly soil and intensely weathered bedrock. The bedrock in the Matthew Creek slide area (Figure 11 and Plate 1) is so decomposed that parts of the rock can be penetrated with a shovel.

The accelerated erosion of the scar face is due in part to the almost vertical angle caused by the initial debris slide. This steepness coupled with the rapid runoff causes the head of the scar to constantly crumble and erode. In winter it has been noted that needle ice is very abundant in the head of the debris slide scars. When these ice crystals growing out of the scar face begin to melt, they tend to

Figure 11. Bedrock exposed in the head of a debris slide scar, located in the Matthew Creek slide area. The bedrock pictured above is a weathered medium-grained sandstone, interbedded with thin layers of metapelite. Photograph was taken in February, 1974.

first at the base (Sharpe, 1938, p. 27). When the ice crystals fall downslope, their load of soil and pebbles also fall for some distance. A single frost may displace material several feet down the slope, greatly augmenting the erosion of the scar face.

The flow tracks and stream channels in their upper courses have gradually refilled or partly refilled with colluvium and alluvium. In the lower and flatter sections of the stream channels where deposition occurred during the flood, piles of boulders and cobblestones can still be identified. The shape of these deposits vary from irregular mounds to ridges which are roughly parallel to the channel bed. This rubble probably accumulated behind dams of trees and other vegetation, although this writer was unable to find any plant remains that may have been a remnant of an old debris dam. The lack of woody material is most likely due to the rapid decay caused by the moist humid climate. In addition to the decay the local residents cut and removed most of the larger trees (personal conversation) shortly after the flooding waters receded.

Along the lower course of Matthew Creek, there can be seen several ridges of rubble located in the present stream channel (Figures 12 and 13). The length of these deposits range from 50 to 100 feet (15-30m), parallel to the direction of stream flow, and they stand several feet above the channel floor. There could be several explanations for the formation of these deposits. The rock material may have accumulated at some stage during the flood or resulted from a flood prior to the storm of 4-5 August 1938, or be constantly reworked

Figure 12. Rock deposited in Matthew Creek below the mouth of draw 3 (Plate 1), which can be seen in the extreme right hand side of the picture.

Source: Tennessee Valley Authority, Hydraulic Data Branch Report 976-1938, photograph No. 4478D, taken on 8 November 1938.

Figure 13. A recent view of the rock debris shown in Figure 12, page 49. This ridge of rubble is located in the middle of the present stream channel. This picture was taken in January, 1974, from approximately the same viewpoint as Figure 12.

material which has been shaped by floods and stream flow over the years. The stream at present has cut around these linear islands and in some places flows over bedrock. It has been suggested by Hamilton (1961) that much of the alluvium and colluvium in the study area was formed when coarse debris was shed from the slopes in a much greater quantity than at present. This may have been during a cold period such as the Wisconsin glaciation, when vegetation was less and increased frost action assisted the movement of debris. This theory could account for some of the great amount of rubble that is seen in the stream beds and on the slopes of the study area. It is the opinion of this writer that most of the ridges of coarse debris in the lower stream channels are a direct result of a flood or floods that have occurred during Holocene time and have been altered over time by postflood streamflow.

In the channels and flow tracks the soils are thinly scattered between the boulders and cobbles filling in depressions along with the forst litter. The tops of some of the larger debris piles have been covered by a thin layer of soil and decaying vegetation. In the narrow bottoms along the lower stream channels alluvial soils have developed. These are classified as the Barbourville and Jefferson series (Soil Survey, 1956). These soild are well drained, silty to sandy, brown, 20 to 30 inches (51-76cm) thick and contain numerous blocks of coarse sandstone, slate and shale. As noted by Moneymaker (1939), immediately after the flood, the deposits that formed behind debris dams "very closely resemble the small bottoms along the streams in cultivation at the time of the cloudburst."

III. REVEGETATION

The rugged terrain of Webb Mountain has created a geographic segregation of groups of species (Appendix C), related to environmental selection. The relationship between geomorphic processes and vegetation is explained by Gilbert's (1909) analysis of slopes. According to Gilbert there are two domains of erosion: (1) stream sculpture associated with concave profiles and (2) creep associated with convex profiles. The framework can be applied to the Webb Mountain area. The domain of stream sculpture is the area of debris slide scars, flowtracks and channelways. Some of the steep slopes may be included in this domain, when heavy rains and cloudbursts cause debris to move downslope by the action of sheetwash. The domain of creep includes the noses of ridges, the upper portion of the steeper slopes, water blowout hollows, above and around the slide scars and to a lesser degree along the banks of stream channels.

The topographic domains, which are controlled by the geomorphic processes, in turn affect the distribution of species and forest types (Hack and Goodlet, 1960). This supports the view by Gleason (1926) that plants, after migration, adjust to their environment through space and time. The vegetation of Webb Mountain is roughly coincident with the topographic forms which create a difference in the environment. The concave-upward profiles of the lower slopes generally support cove hardwood and closed oak forests (A-pendix C). Similarly the convex-upward slopes of the ridges generally support closed oak and pine stands (appendix C).

On Webb Mountain the effect of the cloudburst of 4-5 August 1938 and the ensuing debris slides and flooding has caused local changes in the environment and subsequent adjustment of the vegetation to these changes. The state of the vegetation in the study area prior to the debris slides can be ascertained from historical records and old photographs (Pearsall, 1959; T.V.A., 1938). The top of Webb Mountain between and including the upper reaches of Matthews Creek and Laurel Branch was partially burned over and in 1938 was in laurel and second growth timber. The lower reaches out of the areas of major debris slides on the south side of the mountain were about 50 percent cultivated and 50 percent wooded. The north slope of the mountain in the area of debris slides was also in heavy second growth timber and the lower reaches were somewhat less cultivated than on the south side.

The revegetation of the debris slide areas is closely associated to the geomorphic processes presently working within the slide scars, flowtracks and stream channels and the surrounding vegetation. In the scar heads, the vegetation is usually sparse or absent due to erosion of the scar face and lack of soil (Figure 14). In the lower region of the slide scars and flow tracks where erosion is less evident and some shallow soil has formed, vegetation is stunted and deformed by creep. The revegetation processes become more advanced away from the slide scars toward the down stream areas of deposition.

According to Flaccus (1959), the revegetation species of the slide area is strongly affected by the make-up of the surrounding forest. Generally, the processes of "stocking" in the damaged are "are inversely

Figure 14. A recent view of a debris slide scar at the head of draw 3 (Plate 1) in the Matthew Creek area. Pictured above is a close up view of the slide scar on the left, shown in Figure 6, page 37. This picture was taken in January, 1974.

proportional to the distance from seed sources at the edge." The result is the older and larger trees are along the edges and revegetation moves progressively inward. This idea is reflected by the revegetation processes in the Webb Mountain debris slide areas. From field observation it can be seen that the slides in the closed oak-cove, hardwood forest environment are supporting this same type of vegetation in a stunted form. Similarly the slides in the closed oak-pine forest are dominated by stunted species of the encircling vegetation.

The better developed vegetation grows along the edges of the scars and in isolated small patches of soil and debris that have developed behind boulders and in the lower sections where the slope angle is less and the runoff is reduced. Flaccus (1959) states that islands of vegetation and soil are sometimes left in site by the slide processes. It is hard to recognize this in older slides (Flaccus, 1959) and none can be recognized for certain in the study area.

Within the debris slide, scars and flow tracks in the cove-closed oak hardwood forest the trees are sampling-size (Figures 15 and 16). The diameter of the stems varies from just under one inch (2.54cm) to just under two inches (5cm). The canopy averages from 10 feet (3m) to 15 feet (4.5m) high. The dominate tree species is oak, followed by maple, and occasionally, hemlock and dogwood are growing in the scars. The major species of shrubs are rhododendron and mountain laurel. The revegetation in the closed oak-pine forest slide area is similar to the cove-closed oak hardwood forest slide revegetation. The hardwoods are mainly sapling-size oaks and the shrubs are mountain laurel and

Figure 15. A debris slide scar located near the head of draw 5 (Plate 1) in the Matthew Creek area. Few, if any, trees have been able to grow in the scared area. This slide appears to have occurred mainly within the soil mantle. Weathered bedrock is exposed in the face of scar head (dark area at the top of slide scar). The slide scar pictured above can be compared to the slide shown in Figure 5, page 35. This picture was taken in January, 1974.

Figure 16. A water blowout scar in the lower part of draw 4 (Plate 1) in the Matthew Creek area. A few small saplings have been aboe to develop in the depression. The scar pictured above can be compared to the water blowout scar pictured in Figure 10, page 44. This picture was taken in January, 1974.

rhododendron. The major difference is the development of pitch pine which dominates the debris scars and flow tracks. Many of these pines have reached a diameter of over six inches (15.2cm) and seem to grow equally well in all areas of the scars (Figure 17).

Revegetation of the lower channels and stream courses where deposition occurred is much more advanced than on the scarred areas above them (Figure 18). The vegetation in the lower reaches is mainly cove hardwood forest species with overlapping species from the closed oak forest. The diameter of many of the trees is well over six inches (15.2cm) and the shrubs are very thick, dominated by rhododendron and laurel.

IV. INTERPRETATION AND EVALUATION OF AIRBORNE IMAGERY

The scarred areas caused by the debris slides and flooding in the study area can be readily identified from the panchromatic black and white aerial photographs taken a short time after the storm of 4-5 August, 1938 (Figures 19 and 20). Additional aerial imagery obtained at various intervals since the debris slides occurred portray the gradual healing processes of the modified slopes (Figures 20 to 23). A combination of remote sensing techniques (Figures 22 and 23) proved to be useful in approximating the number and location of the debris slides.

Several flights were made over the Webb Mountain debris slide areas by the University of Tennessee DC-3 research aircraft. On the first four flights, the plane was equipped with a Hasselblad 500 EL

Figure 17. A water blowout scar located above the head of draw 4 (Plate 1) in the Matthew Creek area. Several Pitch Pines, 3 to 6 inches in diameter have developed in the scar. This picture was taken in January, 1974.

Figure 18. Revegetation of a channel located in draw 5 (Plate 1) in the Matthew Creek area. The diameter of many of the hardwoods which have developed in the channel is over 6 inches. The picture above can be compared to the channel shown in Figure 7, page 40. This picture was taken in January, 1974.

Figure 19. Black and white panchromatic, vertical aerial photograph of Webb Mountain, taken September, 1938. Approximate scale 1:48000, North at left.

Source: Tennessee Valley Authority, Maps and Surveys Branch Chattanooga, Tennessee, photograph No. 164-4A-13.

Figure 20. Black and white, vertical aerial photograph of the major debris slide area of Webb Mountain. Photograph was taken on 6 September 1938. Approximate scale 1:20,000. North at left.

Source: Cartographic Archives Division, National Archives and Record Service, Washington, D.C. Photograph No. AOB29-23.

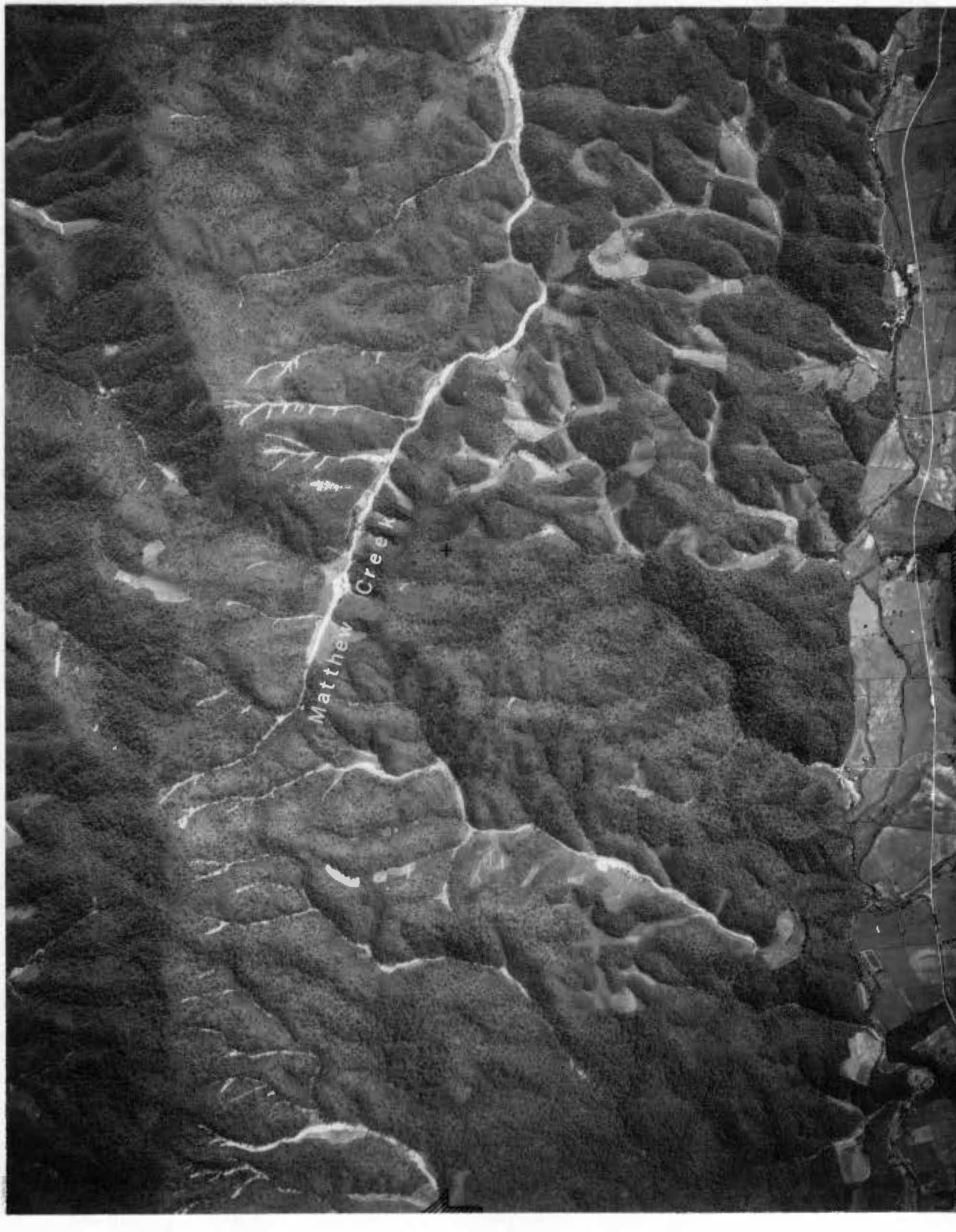

Figure 20.

Figure 21. Black and white panchromatic, vertical aerial photograph of Webb Mountain, taken 29 April 1961. This photograph when compared to Figures 18 and 20 portrays the gradual healing of the slide scars and stream channels. Approximate scale 1:36,000. North at left.

Source: Tennessee Valley Authority, Maps and Surveys Branch, Chattanooga, Tennessee. Photograph No. 164-8A-10.

Film type 8401 (see Table VIII)
Approximate Scale 1:15,000

Film type 5242 (see Table VIII)
Approximate Scale 1:14,400

Figure 22. Vertical aerial 70 mm Hasselblad Quadricamera System Black and White Photographic Imagery; contact prints of identical frames, covering part of the Matthew Creek slide area. North at top.

Film type 2448 (see Table VIII)
Approximate Scale 1:44,000

Film type 8443 (see Table VIII)
Approximate Scale 1:18,000

Figure 23. Vertical Aerial 70mm Hasselblad Quadricamera System Color Photographic Imagery. Contact prints of identical frames, covering part or all of the Matthew Creek slide area. North at top. For comparison with black and white imagery, see Figure 22, page 65.

quadricamera system, utilizing four different emulsion/filter combinations to obtain simultaneous coverage of the scarred zones (Table VIII). These emulsion/filter combinations were selected for their potential use in terrain soil and vegetation analyses, as reported by Anson (1968), Kuhl (1970, and Northrop and Johnson (1970). It was hoped that the remove sensing methods applied by the quadricamera system would depict the limits of the debris slide zones by enhancing the contrast of vegetation and moisture between the scarred zones and the surrounding area.

One flight was flown with a Daedalus Thermal Infrared Line Scanner System equipped with roll compensation (Table VIII). This technique was used to measure the small ground temperature differences that may exist in the areas modified by debris slides and the adjacent areas. A wavelength of between 8 and 14 microns was chosen because this bracket's the wavelength of peak energy equivalent to the earth's average temperature of 20° Centigrade (Sowers, 1972). Pre-dawn imagery was used in hope that the slide zones would be cooler, after energy was lost during the night by radiation, than the surrounding area protected by a heavier growth of vegetation.

The thermal imagery was disappointing because the quality was reduced by problems of scale, created by the rough terrain and movement of the aircraft from a level, straight flight path. Other difficulties with the scanner and processing of the tape combined to further distort the imagery making it difficult to identify the slide areas. However, large features such as ridge crests, steep valleys and large streams could be detected.

TABLE VIII

EMULSION/FILTER COMBINATION AND SCANNER FACILITIES USED ON REMOTE SENSING MISSIONS OVER WEBB MOUNTAIN

Hasselblad 500EL Quadricamera System - 80 millimeter Lenses	
Date	**Film Type**
March, 1969	Kodak Ektachrome MS Aerographic Film Type 2448 (Estar base) Hasselblad Haze Filter
May, 1969	Kodak Infrared Aero Film Type 5424 - Wratten 25 (red) Filter
August, 1969	Kodak Plus-X Aerecon Film Type 8401 Hasselblad Haze Filter
November, 1970	Kodak Ektachrome Infrared Aero Film Type 8443 - Wratten 15 (orange) Filter
April, 1970	Daedalus Thermal Infrared Line Scanner System
	3600 RPM-120 line scan per minute
	Roll compensation - 120 field of view
	Thermal resolution 1/4° Centigrade
	In flight magnetic tape recorder (Two AM and two FM Channels)
	8-14 micron band, pre-dawn flight

An analysis of the various kinds of imagery used in the Webb Mountain slide area indicates that there are some significant differences. The false color (Ektachrome Infrared Aero) proved to be the most useful imagery in detecting the revegetated slide scars. The pancromatic black and white (Plus-X Aerecon) and black and white infrared (Infrared Aero) are also very useful, especially if several different look angles are employed. It is this writer's opinion that remote sensing reconnaissance in the study area was too limited to estimate the true value of the technique's capabilities compiled by Wilson (1969). Although debris slides were not included as a specific category, the sensors were appraised for storm effects. Four seasonal coverages, to include imagery of the vegetation in full bloom and at peak fall color, would obtain additional information to evaluate the potential of remote sensing techniques in the detection of old debris slide zones.

CHAPTER VI

PLAUSIBLE SLIDE LOCALIZING FACTORS AND ORIGINS

I. INTRODUCTION

The causes of debris slides and the distribution of these slides is related to the complex interaction of a group of factors such as meteorological, climatological, slope angle, hydrological, geological, pedological, vegetational and cultural. Two primary factors associated with slide activity are: (1) prolonged and/or (2) intense precipitation and steep slopes, but other factors must also be investigated. According to Varnes (1958), the cause and distribution of slides can seldom be attributed to a single factor. An understanding of the geomorphic processes associated with debris slides is vital to solving problems of engineering geology in areas of potential slides.

II. METEOROLOGICAL AND CLIMATOLOGICAL FACTORS

The frequency, size and character of storms are important factors in producing debris slides. Major storm systems may result in widespread occurrence of slides. Locally intense cloudbursts, associated with thunderstorms, limit the slides to a small area. It is difficult to calculate accurately the recurrence interval for slide producing storms in the Webb Mountain area. The rate and amount of precipitation necessary to cause debris slides is unknown, other controlling factors vary considerably from one site to another, and records of rainfall are too limited to provide enough data to determine the frequency of local intense storms.

Figure 4, page 34, assembled by Bogucki (1970) and Clark (1973), is a record of storms known to have produced debris slides in the Appalachian Highlands south of the glacial border. Detailed precipitation data are very limited and because debris slides occurred before the storm ended, the values exceed the precipitation needed to produce the slides. According to Bogucki (1970), for a period of 33 years from 1938 to 1970, the recurrence interval for slide generating storms is 3.0 years in the unglaciated Appalachian Highlands. A study of rainfall intensity and frequency by Yarnell (1935) indicates that rainstroms of the intensity which produced slides elsewhere have a recurrence interval of more than 100 years in the Great Smoky Mountains. The interval for these storms occur over any small area and cause debris slides probably has a return period much longer than 100 years.

The cloudburst of 4-5 August 1938, that produced the debris slides on Webb Mountain, was a locally intense storm of short duration associated with a series of thunderstorm cells along the North Carolina-Tennessee state line. The Tennessee Valley Authority classifies an intense storm as one which has one or more inches of rainfall in one hour or three or more inches of rainfall in 24 hours. Of the 341 intense rainfalls recorded in and adjacent to the Great Smoky Mountains National Park, for a period of 31 years from 1937 to 1968, only two storms have been accompanied by debris slides. One, of course, is the Webb Mountain storm, the other is a storm of 1 September 1951 over

Mt. Le Conte and Sugarland Mountain area (Bogucki, 1970), five miles south of the study area. The frequency for stroms of this type is greatest during the summer months (Table II, page 13) but extreme rainfall is not confined entirely to the summer period.

The Webb Mountain cloudburst lasted four hours during which time the rainfall exceeded 12 inches (30.4cm) near the storm center. The storm extended over an area approximately two miles (3.2km) long and 1/2 to 3/4 of a mile (.8-1.3km) wide (T.V.A., 1938). The areas of major debris slide occurrence can be directly correlated to the path of intense rainfall. Most of the major debris slides developed within the limits of the storm center. According to T.V.A. (1938), the most intense rainfall occurred on the south side of the mountain in the Matthews Creek watershed. Similarly, this is the area which produced the most well developed and numerous debris slides. It should be stated that though 12 inches (30.4cm) or more of rainfall was recorded in the slide area, indications are that the debris slides occurred in the first part of the storm when considerably less rain had fallen. Moneymaker (1939) states that the sliding took place sufficiently early for the debris from the slides to be swept clear of the slide tracks and the scars modified by gullying.

This writer agrees with Moneymaker (1939) and T.V.A. (1938) that the origin of the debris slides was mainly the result of the saturation of residual material, the water increasing its weight, making the mass somewhat plastic and ultimately serving as a lubricant.

The localizing influence of cloudbursts on debris slides has been described by Bogucki (1970) in the Great Smoky Mountains National Park and by Schneider (1973) in the Renick of West Virginia. According to Horne and McGuire (1960), these intense thunderstorms are triggered by orographic lifting of moisture laden air masses by the mountains. Although these cloudbursts occur locally on the average at long intervals, they could conceivably occur in any year.

It should be mentioned that lightening associated with thunderstorms may be a factor in influencing slide occurrence. Varnes (1950) states that vibrations from thunder may cause water in small voids and bound around mineral particles in the soil to become free and locally oversaturate and initiate sliding. Schneider (1973), and Williams and Guy (1973) report intense lightening during the storms which occurred over slide areas. Personal conversations and Pearsall (1959) reveal that flashes of lightening continuously illuminated Webb Mountain during the 4-5 August 1938 storm. Descriptions of the lightening indicate that it may have been of the sheet or horizontal type reported by Williams and Guy (1973).

III. SLOPE AND OTHER GEOLOGICAL FACTORS

For any potential slide area, movement is limited by the slope form and by the slope angle. The bedrock of Webb Mountain underlies S-shaped slope profiles with gentle crests and valleys and steep intermediate segments. These slope profiles are relatively uniform in shape, but slope angles vary which apparently is the more important slope slide localizing factor. In the study area, the frequency of debris slides increases with increasing gradient because the force required to start a particle moving down a slope decreases as the slope steepens (Zingg, 1940).

Recorded debris slides have occurred on slopes with a range of values. Sharpe (1938) reported that debris slides have slopes that range from 20° to 40° (36% to 84%) for the scar head and flatten to 15° (26.8%) near the terminus. In the White Mountains, Flaccus (1958) reported slides on slopes which range from 25° to 35° (47% to 70%). Bogucki (1970) reporting on the slide area of Mt. Le Conte found that the slope of the slide scar heads averaged 40° (84%), with a range of 35° to 44° (70% to 96%). Schneider (1973),working in the Petersburg and Renick area of West Virginia, stated that slides occurred on slopes ranging from 25° to 31° (46% to 60%).

Field data from the Webb Mountain debris slide areas (Table VI, page 30) indicate that slide scars occur on slopes ranging from 32° to 43° (62% to 93%). Many of the scars have short slope segments which are steeper than the average slope gradient. According to Williams and Guy (1973), debris slides tend to be initiated in the zone where the local gradient is the steepest and this may be true in the study area.

The attitude of the bedrock of Webb Mountain appears not to be a significant factor in localizing the debris slides. The strike tends in a general east-west direction with a high angle of dip to the south. The angle of dip ranges from 60 to 90 degrees in the areas of debris slides (Field measurements and Hamilton, 1961). Although slides occurred on both the north and south slopes of the mountain, the high angle of dip to the south may have had some effect on the size and frequency of debris slides on the south side of the mountain in association with the path of intense rainfall.

The lithology of the bedrock in the slide zones is relatively consistent and is reflected by the soil which exhibits little variation. The degree of bedrock weathering ranges from slightly weathered in the upper unit rocks of Webb Mountain to weathered and saprolitized in the lower unit rocks. The distribution of the slides appears to have been affected very little by the lithology.

Flaccus (1958) and Bogucki (1970) found no correlation between slide occurrence and lithology. Bogucki (1970) found that there was geologic control of slide location by high angles of dip in the Mt. Le Conte-Sugarland Mountain area.

Water blowouts are probably the only features that were locally controlled by the nature of the bedrock. Eisenlohr (1952) and Hack and Goodlet (1960) believe that the origin of water blowouts may be the result of hydrostatic pressure of water in the ground when it is concentrated at one horizon by the fracture patterns and bedding planes. Although groups of two or three water blowout scars are randomly scattered through the study area, the scars in a single group are located along the same general level of elevation. This pattern lends credence to the hypothesis involving hydrostatic pressure.

IV. PEDOLOGICAL AND VEGETATIONAL FACTORS

Soils and vegetation, interrelated with other factors, appears to have some bearing on the localization of debris slides (Schneider, 1973). To provide data on the relationship of slide occurrence to these two factors, a study of soil characteristics and vegetation patterns was undertaken in the study area. The location and a detailed description of 12 pits are noted on Plate 1 and in Appendix B. Soil samples were collected from several of these pits dug adjacent to slide scars and on slopes that did not develop slides but are located within the area of debris slides.

Appendix B indicates that there is little difference in soil thickness on the slopes investigated in the study area. Available information indicates the precipitation from the cloudburst was probably intense enough to saturate all soil thickness within the slide area. According to Moneymaker (1939), the debris slides of Webb Mountain were initiated "by the saturation of residual material, the water increasing its weight and serving as a lubricant." Although the angle of slope controls the development of soils, the variations in soil thickness and slope angle is so minor within individual slide zones and throughout the slide areas that the soil thickness appears to be of slight localizing influence. The minor variations in soild thickness and character may be the reason for the herringbone-patterned slide complex (Jones, 1973) that developed on some of the slopes (Figure 20, page 63).

In some areas of debris slides, mass movement has been associated with hydration of swelling clay materials in the residual material covering the slopes. The expanding clay minerals, especially the 2:1 lattice by absorbing water may even cause bedrock to swell (Yatsu, 1967).

Handy and Williams (1967), Erskine (1973), and Jones (1973) conclude that slope stability in many areas of alides is dependent on the proportion of montmorillonite in the clay-size components of shales and soils.

The clay minerals of the Ramsey soils in the study area were investigated by X-ray analysis. The Ramsey soil which has developed on the slopes of Webb Mountain occurs in all the areas of debris slides. The soil is classed as lithosol (Soil Curvey, 1956) which is azonal, having no clearly defined horizons, consisting mainly of sandy to silty clay and weathered rock fragments. The lack of pronounced horizons in the soil is an indication of instability of the slope surface, the soil constantly being formed and removed by the rapid erosion of the steep slopes.

The clay samples for X-ray analysis were collected from undisturbed soil profiles in six pits located at various elevations (Plate 1) in major debris slide areas. Samples were taken from each pit directly below the humus layer continuously to the bottom of the pit. The average depth of the six pits was 29 inches (74cm). The sample preparation technique of pelletizing, as described by Hidalgo and Renton (1970), was employed for the X-ray diffraction analysis of the clay minerals. The advantages of the pelletizing technique include minimizing the errors inherent in the preparation of slide-mounted samples, simplicity, and speed of preparation, reproducibility of results and an enhancement of basal reflections. Several samples from the study area were both pelletized and slide-mounted. This comparison between the two methods illustrated the significant increase in the intensities of the basal reflections of the pelletized samples.

The X-ray diffraction of the soil samples from the Webb Mountain debris slide area showed kaolinite and vermiculite to be the dominant clay minerals. Detrital mica was recognized under magnification which is partially responsible for a 10-A° peak indicating a mica or mica-type clay mineral such as illite (Grim, 1968). The lack of 2:1 expanding lattice clays in the soils excludes the possibility that the slides were associated with hydration of swelling clay minerals.

There appeared to be no major relationship between soil properties and debris slide location in the Webb Mountain area. The soil data, however, can be compared with other slide areas in the Appalachians. Hack and Goodlet (1960), Bogucki (1970), Schneider 91973), and Williams and Guy (1973) all report similarities in soil thickness and a lack of soil profiles in the areas of debris slides.

It is generally believed that forest cover will not prevent the occurrence of slides but it is a localizing factor in that is reduces the number of slides. Scott (1972) and Schneider (1973) conclude that a healthy forest will reduce the incidence of debris slides. However, Bogucki (1970) documented slides in a thick virgin forest and Faccus (1959) stated that a mature forest increases infiltration, reduces runoff and allows greater water retention during storms, all of which tends to increase slide susceptibility.

Pearsall (1959) felt that the debris slides of Webb Mountain were directly related to the state of vegetation at the time of the storm of

4-5 August 1938. The following is a description of the Webb Mountain area between 1900 and 1938 by Pearsall (1959):

> Geologists who surveyed the area between 1900 and 1905 noted that the major creek valleys and lower slopes were cleared and cultivated. The higher slopes were practically untouched by farmers at that time, although lumbermen had already removed the best timber. . . . As the years passed, all the original forest was cut, and the steeper slopes came under cultivation. The streams took on a reddish or yellowish-brown color from suspended soil. Damaging floods became frequent.

Pearsall (1959) concluded that in 1900 the land might have been able to withstand the intense rainfall that causes debris slides, but by 1938 the land was unable to absorb the unusual amount of water.

No doubt the destruction of the forest cover in the cultivated areas increased the incidence of landslides. Unwise methods of farming, logging and burning have often been associated with landslides (Hack and Goodlet, 1960 and Schneider, 1973). The fact is that the majority of debris slides occurred out of the areas of cultivation on Webb Mountain. Historical data and ground photographs (T.V.A., 1938) give evidence that the major slide areas were covered by thick second growth timber. The slides originated in several different forest associations of mixed hardwoods and pines. In some areas, this writer has observed less modification by slides on southwest facing slopes covered at present by a thick growth of pines. If the condition of the timber was similar when the slides formed, the pines may have been a localizing factor. It should be noted that most of the southwest facing slopes are slightly less steep than other slopes in the debris slide area. Bogucki (1970) stated that in the virgin forest of his study area, the vegetation type has no relationship to the distribution of debris slide scars.

V. CULTURAL FACTORS

Aside from the logging operations and farming methods already described under pedological and vegetational factors, there were no other apparent cultural features which existed in 1938 that could have influenced the debris slides in the study area. However, presently there are developments under way that most assuredly will affect the susceptibility and localization of debris slides on Webb Mountain.

On the south side of the mountain an extensive subdivision of summer cottages and weekend cabins is being developed, and the proposed route of the Foothills Parkway crosses above the subdivision (Figure 24). The bedrock underlying the areas of development ranges from the lower unit rocks of webb Mountain (Hamilton, 1961), described in Chapter II of this study, to the feldspathic metasiltstones of the Pigeon Formation. Much of the bedrock is weathered in some places to the point of becoming a saprolite. Locally the bedrock is complexly folded and fractured, but generally the rocks strike east-west and dip to the south.

Due to the continued construction, the lower south side of Webb Mountain is becoming a residential area. The steep slopes have been divided into numerous small lots and criss-crossed with roads. The locations of the buildings range from the bottoms of narrow valleys (Figure 25) to benches cut into the side of the slopes (Figure 26). The roads switch back and forth across the contours and cut above and below the building sites (Figure 27). Most of the present buildings are located on the metasiltstones of the Pigeon Formation and are beginning to extend up the mountain into the thin bedded clastic rocks of the

Figure 24. Aerial view of the south side of Webb Mountain. The residential and recreational development under construction can clearly be seen. The dashed black line represents the proposed route of the Foothills Parkway. The major area of slides lies directly above the parkway route. This photograph, when compared to Figure 20, page 63, illustrates the extent to which the slides and flow tracks extend into the areas of development. Approximate scale 1:13500, north at top. Photograph taken 8 March 1972.

Source: Continental Aerial Surveys, Inc., Alcoa Highway, Louisville, Tennessee.

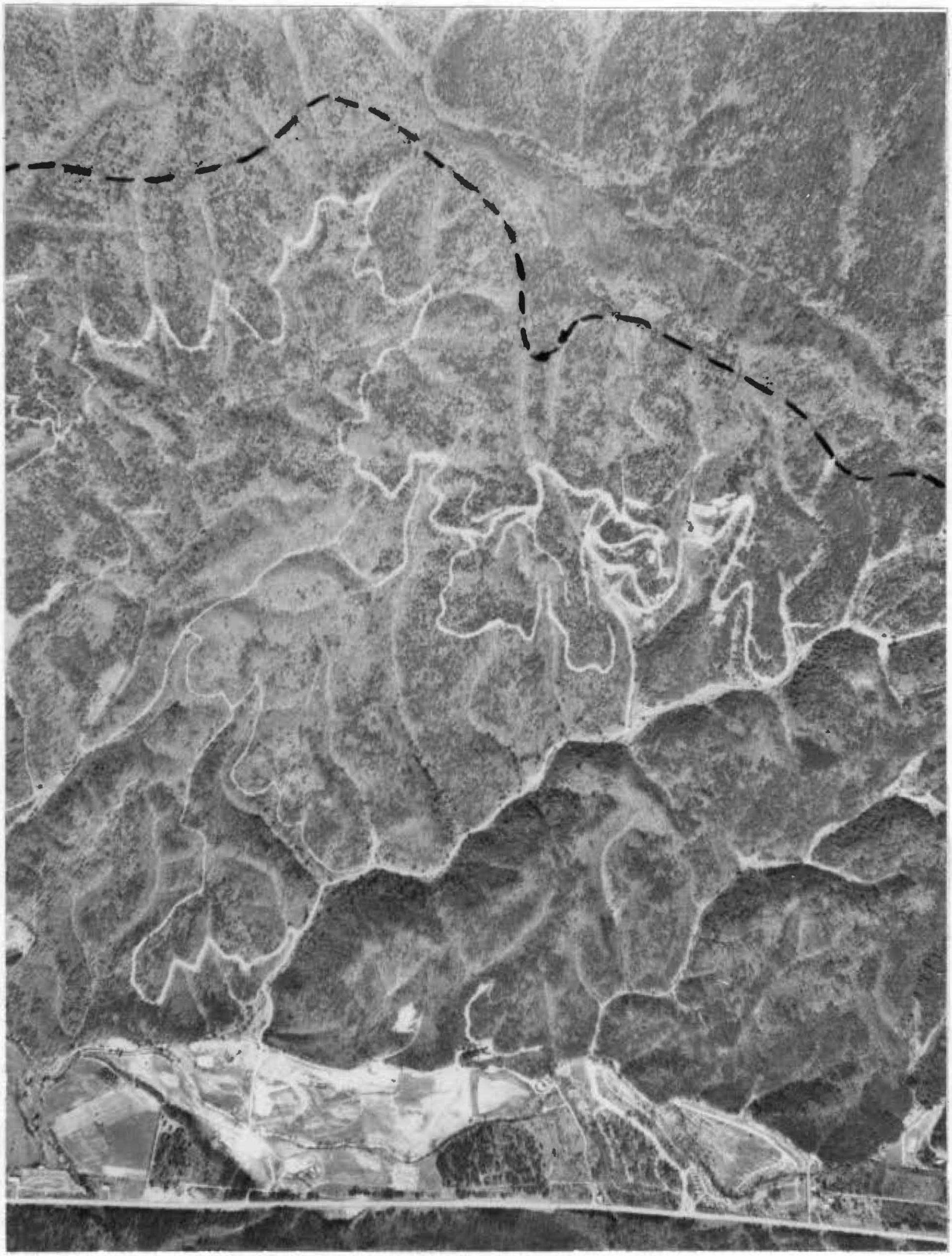

Figure 24.

Figure 25. Building resting on concrete blocks located in the middle of a stream channel. This stream, which flows in a narrow valley, has been constricted by the construction of a road along its bank.

Figure 26. Building located on a bench cut into a hillside. The average slope angle is 35° (70%). This picture was taken from a road which is cut below the house.

Figure 27. Building located on a hillside with an average slope angle of 38° (78%). The slope angle has been modified to 34° (67%) at the building site. A road cut can be seen at the bottom of the picture directly below the house.

lower unit rocks of Webb Mountain (Hamilton, 1961). The bedrock underslying the housing development is in most places weathered and fractured enough so that the roads could be bulldozed and very little blasting was necessary.

Powers (1971) stated that there are very severe limitations to the development of residential areas and roads in the foothills of the Great Smoky Mountains. The steep topography is unstable; many of the building sites are located on slopes with gradients ranging from 34° (67%) to 39° (81%). The unstable condition of the thin soil mantle is evidenced by the curved tree trunks (Figure 28) deformed by the creep of the regolith. The lots with septic tanks will add water to the soil and weathered bedrock which could aggravate the already unstable condition of the slopes, especially during a severe storm. Flooding problems may develop because the subdivision is located in the area of channelways stemming from the old debris slides. The flow tracks from many of these slides extend down the mountain through the area now under development. These channels could again carry debris and runoff caused by cloudbursts occurring over the crest of the mountain.

The impact that highways and small roads have on the environment of the steep mountainous topography of the study area depends on many factors. Roads constructed on the oversteepened slopes (greater than 30°, Bailey, 1971) increase the potential for debris slides. Road related slides have been correlated with slope gradient and storms (Bailey, 1971). Fredriksen (1963, p. 4) concluded that roads built in an area of unstable topography inevitably upset the equilibrium of the

Figure 28. Lots for building sites are located on the hillside pictured above. The unstable condition of the slope surface is evidenced by the curved tree trunks, deformed by the creep of the soil. The slope angle averages between 38° to 39° (78% to 81%).

slopes. The development of roads in steep mountainous areas constitutes a calculated risk in spite of precautions taken in road location and construction.

The construction of the Foothills Parkway and many small roads of the subdivision on Webb Mountain tend to intensify the unstable conditions that now exist on the slopes. Roads constructed on the steep slopes tend to have high cutbanks, long fill slopes and poor alignments. Because of the steep slopes and deeply incised drainage (Bailey, 1971), the stabilization of cuts and fills is difficult to achieve. Roads constructed below many of the building sites often undercut naturally unstable slopes or deposit excessive material on slopes already at the angle of repose. The proposed route of the Foothills Parkway passes through part of the area of old debris slides discussed in this study. The recognition of the existing slide scars should serve as a warning that the area has been unstable in the past.

In addition to the problems related to oversteepening of the slopes, the construction of roads can upset the hydrogeologic environment to the point of permitting sliding. Parizek (1971) states that cut, fills, abutments and retaining walls often impede the natural flow of surface and subsurface water. In areas of inactive slides along the route of the Foothills Parkway, the drainage channels developed below the slide scars may be restricted. This could cause an increase in ground water and upset the equilibrium and indice additional sliding. Also, the surface runoff during heavy rains may build up behind culverts because of inadequate size or plugging of the culvert by debris. This causes saturation of the fill slope and could trigger mass soil movement (Bailey, 1971). Another cause of slope failure is related to the flowing ground water above compacted roadways. Rapp (1963) and Parizek (1971) report that the highly compacted roads appear to interfere with the subsurface soil water movement. During an intense rainfall, the seepage will exert pressure at the foot of the slope above the road and burst through. Terzaghi (1950) concluded that once the failure of the lower part of the slope occurs, the upper part slides due to the absence of support.

Any major development projects in the inactive and potential slide areas of Webb Mountain should be avoided. If construction is necessary, an understanding of the geologic and hydrologic conditions may aid in the prediction and controlling of debris slides and related flooding.

CHAPTER VII

SUMMARY AND CONCLUSIONS

On the night of 4-5 August 1938, a severe cloudburst occurred along the crest of Webb Mountain, Tennessee. Numerous debris slides and flooding resulted from the intense rainfall. Thirty-six years after the storm, debris slide scars and the related channel modifications are still prominent features of the mountain topography.

Available historical data, aerial photographs and field observations made it possible to locate and map the areas of debris slides. Judging from the extent and intensity of slope modifications, the storm center appears to have been located over the crest of the mountain, between the headwaters of Laural Branch and Matthew Creek. Over 100 slide scars were recognized in the study area of which 40 occur in the Matthew Creek area where apparently the greatest amoung of rainfall and runoff occurred.

Debris slides were located with few exceptions in slight depressions, the heads of major valleys, and tributary draws. Movement was initiated by sliding, the mass of material remaining somewhat intact, and as this mass moved down the slope, the slump block disintegrated and developed an element of flow. Mass movement was of three distinct types in the Webb Mountain area: (1) debris slides that developed on the steep slopes, (2) slides that formed along channelways initiated by undercutting, and (3) water blowouts which played only a minor part in slope modification.

Slide dimensions and shape vary. The scar heads range from crescent to rectangular shape. The long profile and cross profile are slightly concave. The depth, below the slope surface, of the slide scar floor varies from 2 to 4 feet (.6-1.2m). The width of the slide scars ranges from 10 to over 80 feet (3-24m). Slope angles in the slide areas average 37° (75%). Slides occurred mainly on the south side of Webb Mountain on slopes facing a southerly (S-45°-E to S-45°-W) direction.

According to the available data concerning debris slides in the Southern Appalachian Highlands, the outstanding factor associated with the sliding is intense precipitation. Factors other than severe rainfall may make the area susceptible to sliding and influence the localization of slides. Debris slide origin and localization in the Webb Mountain area were controlled by a complex interaction of numerous factors. Prolonged and intense rainfall along with the steep slops angle are the most important factors contributing to the formation of slides in the study area.

Intense precipitation was a critical localizing factor; the rainfall exceeded 12 inches (30cm) and lasted about three hours. The recurrence interval for a storm similar to the 4-5 August 1938 cloudburst is probably greater than 100 years, but a slide producing storm may occur at any time and most probably in the summer months.

Slope angle and form appear to be the second critical factor in slide localization. Slides developed on the steeper slopes which range from 32° to 43° (62% to 93%), the frequency of debris slides increasing with increasing gradient. Many of the slide scar heads are located on slope segments which are steeper than the average gradient of the slope.

The structure of Webb Mountain appears to have had some influence on debris slide location. The predominant dip of the bedrock is to the south. The steep angle of dip may have influenced the size and frequency of slides on the south side (down dip) of the mountain within the path of the cloudburst. Water blowouts, the result of a concentration of hydrostatic pressure in the ground, were probably locally controlled by the degree of weathering, fracture patterns, and compositional layering of the bedrock.

Field observations and laboratory analyses disclosed that soils within the slide area very little in depth and texture. Minor variations in the character of the soils may have been responsible for the herringbone-pattern slide complex that developed on some of the slopes. The clay-size components of the soil are dominated by kaolinite and vermiculite, detrital mica and possibly illite are also present. The lack of 2:1 expanding clays in the soil excludes the possibility that mass movement was initiated by the hydration of swelling clays.

Erosion of most of the slide scar faces is very active at present, due to the steep slopes and rapid runoff. Needle ice is also an active erosional agent of the scar faces during the winter months. A thin soil mantle has developed in many of the slide scars and flow tracks from colluvium, decaying bedrock and forest litter. The lower reaches of the eroded channels and stream courses have gradually filled in part with colluvium and alluvium. Irregular piles and lenses of rock debris that were deposited in the lower flatter sections of the stream channels during the flood can still be identified. Some of this deposited debris may have resulted from floods other than the 4-5 August 1938 flood.

The vegetation of Webb Mountain is roughly coincident with the topographic forms which create differences in the local environment. Slides originated in cove hardwood, closed oak, and pine forest. The vegetation type apparently had little influence on the distribution of debris slides. The destruction of forest covery may have increased the incidence of slides on the lower cultivated slopes. There is some indication that the thick pine forests that cover some of the higher slopes, along with other factors, impeded the development of slides.

Revegetation of the modified slopes is closely associated to the geomorphic processes at work in the study area. The revegetation of the scared hillsides becomes more advanced down slope in places of deposition. The vegetation is better developed along the edges of slide scars, flow tracks, and channelways. Shrubs and trees become stunted and deformed inward toward the center of the scared areas. The type of species that developes on the slide modified slopes and in the channelways is determined by the surrounding species. Pitch pine appears to grow and develop more readily than the hardwoods in the old slide scars.

Within the major slide area cultural features were minimal prior to the debris sliding. The effect of widespread lumbering on the mountain in the study area had little influence on slide localization, probably because a thick second growth of timber had developed before the 4-5 August 1938 cloudburst. Presently there are cultural factors under development which will have some influence on susceptibility and localization of debris slides in the future. The added impact of the construction of roads and buildings on the steep slopes of Webb Mountain should be considered when evaluating the probability of debris slide occurrence in the future.

The scarred areas caused by debris sliding and related flooding were located and mapped by airborne imagery. Four different emulsion/filter combinations and one thermal scanning mission were flown over the slide area. The Ektachrome Infrared Aero film proved to be the best imagery for the analysis of slope modifications. Four seasonal coverage of the revegetated slide scars would obtain additional information to evaluate the potential of remote sensing techniques for investigating debris slide zones.

Debris slides are an important geomorphic process in valley formation and modification. Slides have occurred in the past and will occur in the future on Webb Mountain. At present, the debris slide scars are still unstable. Erosion is very active, preventing the development of soils and vegetation on the modified slopes. Bedrock is still exposed in many of the slide scars 36 years after the formation of the scars.

The slopes of Webb Mountain have developed long term stability which is defined as slopes not subject to sliding within 100 years or more (Young, 1972). Both passive and active conditions (Sharp, 1938) favor slide occurrence in the study area. The natural passive conditions which exist are: steep slopes, a thin permeable soil, bedrock with dips toward the slopes, and a climatic zone liable to high-intensity rainstorms. The active conditions which initiate the slide movement are: the occurrence of cloudbursts causing intense rainfall and oversteeping of slopes by basal erosion caused by the great amount of runoff concentrated in the stream channels during the cloudburst.

The construction of roads, recreational and residential developments on the steep mountainous slopes of Webb Mountain may effect the slopes in such a way that short term stability will prevail. A complete assessment of the total environment is necessary to detect and understand the conditions favorable to slope failure. Research should be directed toward obtaining data to aid in the detection and prediction of slide producing factors. An understanding of the nature and origin of debris slides may help to solve problems of slope stability.

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APPENDICES

APPENDIX A

A MINERAL ANALYSIS OF THE ROCKS OF WEBB MOUNTAIN

Sample JC 1B-3. Lower division, Webb Mountain, Warden Branch

Dark-gray uniform metasiltstone; contains about 40 percent quartz and feldspar 0.02-0.3 mm in diameter; quartz rimmed and feldspar rimmed and replaced, by sericite, and many sericite masses are probably feldspar pseudomorphs; contains about 57 percent sericite and chlorite finer than 0.01 mm, 1 percent chlorite psuedomorphs after clastic biotite, and 2 percent carbon in 0.005 mm interstitial granules (Hamilton, 1961, p. A-13).

Sample JC 78A-1. Upper division, Webb Mountain, northwest of Jones Gap.

Thinly interlaminated dark-gray slate and silty slate, with a short thin lense of sandy metasiltstone; slate contains 95 percent chlorite and sericite with an average grain size of 0.03 mm, well oriented parallel to the conspicuous cleavage, 1 percent quartz and feldspar, 3 percent clastic biotite, and 1 percent muscovite. Silty slate has 50 percent chlorite and sericite averaging 0.02 mm long, 40 percent 0.02-to-o.1 mm quartz and feldspar, and 5 percent each of clastic biotite and muscovite. Sandy metasiltstone contains 44 percent sericite and chlorite; 55 percent angular strained quartz, 0.1 to 0.5 mm in diameter; 1 percent clastic biotite; and traces of zircon, tourmaline, and magnetite or limenite. Quartz is slightly embayed by matrix, and feldspar much replaced by it (Hamilton, 1961, p. A-13).

APPENDIX B

RECORD OF SOIL PITS
(Locations on Plate 1)

Pit No. 1

Location . . . . Warden Branch area

Placing. . . . . Slope without slide

Slope angle. . . 36° (73%)

Description . . . Dark humus, silty, 4 to 4 inches (10.1 to 12.7 cm) thick. 30 inches (76.2cm) of pale-brown silty to sandy clay and friable rock fragments. The rocks become larger, less weathered and numerous with depth, the color grades to a yellowish-brown. The rock fragments consist of conglomeratic sandstone with a few chips of quartz. Bedrock - coarse and sandstone.

Total thickness. 35 inches (88.9 cm)

Sample taken for X-ray analysis

Pit No. 2

Location . . . . Warden Branch area

Placing. . . . . Adjacent to slide scar

Slope angle. . . 38° (78%)

Description . . . Black humus, sandy to silty 5 inches (12.7 cm) thick. 20 inches (50.8 cm) of sandy orangish-brown clay and friable rock fragments of coarse to conglomeratic sandstone. Rock fragments become more numerous and less weathered with depth, some quartz chips throughout the profile. Bedrock - coarse sandstone.

Total thickness. 30 inches (76.2 cm)

Sample taken for X-ray analysis

Pit No. 3

Location . . . . Warden Branch area

Placing. . . . . Middle of slide scar

Slope angle. . . 37° (74%)

Description . . . Black humus, sandy to silty, 2 inches (5 cm) thick. 8 inches (20.3 cm) of stony, sandy, yellowish-brown clay. Rock fragments are partially weathered, consisting of coarse sandstone and small angular pebbles of quartz. Bedrock - coarse sandstone.

Total thickness. 10 inches (25.4 cm)

Pit No. 4

Location . . . . Jones Branch area

Placing. . . . . Adjacent to slide scar

Slope angle. . . 40° to 43° (84% to 93%)

Description . . . Black silty humus, 3 inches (7.6 cm) thick. 29 inches (73.6 cm) of sandy clay pale-brown and friable rock fragments. Rock fragments increase in number and size and become less weathered with depth. Rock fragments increase in number and size and become less weathered with depth. Rock fragments are coarse to conglomeratic sandstone. Bedrock - sandstone.

Total thickness. 32 inches (81.2 cm)

Sample taken for X-ray analysis

Pit No. 5

Location . . . . Jones Branch area

Placing. . . . . Middle of slide scar

Slope angle. . . 42° (87%)

Description . . . Black silty humus, 5 inches (12.7 cm) thick. 2 inches (5 cm) of brownish-orange silty to sandy clay with numerous rock fragments of coarse to conglomeratic sandstone and chips of quartz. Bedrock - sandstone.

Total thickness. 7 inches (17.7 cm)

Pit No. 6

Location . . . . Jones Branch area

Placing. . . . . Slope without slide

Slope angle. . . 40° (84%)

Description . . . Black silty humus, 1.5 inches (3.8 cm) thick. 24 inches (60.9 cm) of pale-yellowish-brown sandy to silty clay with friable rock fragments. The fragments increase in size and number and become less weathered with depth. The rocks are conglomeratic sandstone and quartz chips. Bedrock - sandstone.

Total thickness. 25.5 inches (64.7 cm)

Sample taken for X-ray analysis

Pit No. 7

Location . . . . Matthew Creek area

Placing. . . . . Adjacent to slide scar

Slope angle. . . 34° (70%)

Description . . . Dark gray to black silty humus, 2.5 inches (6.3 cm) thick. 6 inches (15.2 cm) of orangish-brown sandy to silty clay with a few small friable fragments of coarse sandstone. With depth the soil grades to a yellowish-brown with and an increase in rock fragments of coarse sandstone and shale or weathered slate chips, this layer is 11.5 inches (29.2 cm) thick. Bedrock - sandstone interbedded with shale (slate).

Total thickness. 20 inches (50.8 cm)

Sample taken for X-ray analysis

Pit No. 8

Location . . . . Mathew Creek area

Placing. . . . . In middle of slide scar

Slope angle. . . 36° (73%)

Description . . . Black sandy to silty humus, 1 inch (2.5 cm) thick. Pale-orangish-brown, sandy to silty clay and rock fragments, friable, of coarse sandstone and chips of shale, becoming more numerous and less weathered with depth, this layer is 6 inches (15.2 cm) thick. Bedrock - sandstone interbedded with shale.

Total thickness. 7 inches (17.7 cm)

Pit No. 9

Location . . . . Matthew Creek area

Placing. . . . . Adjacent to slide scar

Slope angle. . . 36° to 40° (73% to 84%)

Description . . . Dark gray to black silty humus, 2 inches (5 cm) thick. 28 inches (71.1 cm) of orange to pale-yellow, sandy to silty clay and friable rock fragments of coarse sandstone and shale or slate. Bedrock - sandstone interbedded with shale or slate.

Total thickness. 30 inches (76.2 cm)

Sample taken for X-ray analysis

Pit No. 10

Location . . . . Matthew Creek area

Placing. . . . . Middle of slide scar

Slope angle. . . 35° (70%)

Description . . . Black sandy and silty humus, less than 1 inch (2.5 cm) thick. 4 inches (10 cm) of orangish-brown, sandy clay mixed with friable rock fragments of sandstone, shale and quartz chips. Bedrock - sandstone interbedded with shale (slate).

Total thickness. 5 inches (12.7 cm)

Pit No. 11

Location . . . . Matthew Creek area

Placing. . . . . Middle of water blowout scar

Slope angle. . . (adjacent to scar) 36° (73%)

Description . . . Black silty humus, less than 1 inch (2.5 cm) thick. 11 inches (28 cm) of orangish-brown sandy to silty clay and quartz chips. Bedrock - sandstone weathered to saprolite.

Total thickness. 12 inches (30 cm)

APPENDIX C

REFERENCE LIST OF NATURAL VEGETATION
(Condensed from R. E. Shanks, 1954)

The following is a list of vegetation types which are associated with Webb Mountain. The list is intended to serve as a checklist and to include all conspicous species even though they may be numerically unimportant. Transitional areas on the mountain included species that appear in two or more physiognomic areas, and widespread species occur in more than one list.

I. COVE HARDWOOD FORESTS

Plants of the cove and sheltered slopes up to about 4500 feet dominated by various combinations of the broad-leaf, deciduous hardwoods.

<u>Dominate Trees</u>

Acer saccharum (SUGAR MAPLE)
Aesculus octandra (YELLOW BUCKEYE)
Betula alleghaniensis (YELLOW BIRCH)
Castanea dentata (CHESTNUT)
Fagus grandifolia (BEECH)
Fraxinus americana (WHITE ASH)
Halesia carolina var. monticola (SILVERBELL)
Liriodendron tulipfera (TULIP POPULAR)
Magnolia acuminata (CUCUMBER TREE)
Prunus serotina (BLACK CHERRY)
Quercus rubra (NORTHERN RED OAK
Tilia heterophylla (BASSWOOD)
Tsuga canadensis (HEMLOCK)

<u>Additional Canopy Trees</u>

Acer rubrum (RED MAPLE)
Betula lenta (SWEET BIRCH)
Carya cordiformis (BITTERNUT HICKORY)
Cladrastia lutea (YELLOW-WOOD)
Juglans cinerea (BUTTERNUT)
Juglans nigra (BLACK WALNUT)
Nyssa sylvatica (BLACK GUM)

Small Trees

Acer pensylvanicum (STRIPED MAPLE)
Acer spicatum (MOUNTAIN MAPLE)
Amerlanchier lavis (SERVICE BERRY)
Carpinus carolinana (BLUE BEECH)
Cornus alternifolia (ALTERNATE-LEAF DOGWOOD)
Hamamelis virginiana (WITCH HAZEL)
Ilex opaca (HOLLY)
Magnolia fraseri (FRASER MAGNOLIA)
Magnolia tripetala (UMBRELLA MAGNOLIA)

Shrubs

Calycanthus fertilis (SWEET-SHRUB)
Clethra acuminata (PEPPER-BUSH)
Gaylussacia ursina (BEAR HUCKLEBERRY)
Hydrangea arborescens (HYDRANGEA)
Kalmia latifolia (MOUNTAIN LAUREL)
Pyrularia pubera (BUFFALO-NUT)
Rhododendron maximum (RHODODENDRON)

Woody Vines

Aristolochia durior (DUTCHMAN'S-PIPE VINE)
Parthenocissus quinquefolia (VIRGINIA CREEPER)
Smilix rotundifolia (ROUND-LEAF CATBRIER)
Vitis aestivalis (SUMMER GRAPE)

Ferns and Club-mosses

Athyrum filix-femina var. asplenioides (LADY FERN)
Dryopteris spinulosa var. americana (SPREADING SHIELD-FERN)
Lycopodium lucidulum (SHINING CLUB-MOSS)
Polypodium virginianum (POLYPODY FERN)

II. CLOSED OAK FOREST

Plants of intermediate to dry slopes dominated by oaks, or originally by oaks and chestnuts.

Canopy Trees

Acer rubrum (RED MAPLE)
Betula lenta (SWEET BIRCH)

Carya glabra (PIGNUT HICKORY)
Carya ovalis (RED HICKORY)
Carya tomentosa (MOCKERNUT HICKORY)
Castanea dentata (CHESTNUT)
Halesia carolina var. monticola (SILVERBELL)
Liriodendron tulipifera (TULOP POPLAR)
Nyssa sylvatica (BLACK GUM)
Quercus alba (WHITE OAK)
Quercus prinus (CHESTNUT OAK)
Quercus rubra (NORTHERN RED OAK)
Quercus velutinia (BLACK OAK)
Robinia pseudoacacia (BLACK LOCUST)

Small Trees

Acer pensylvanicum (STRIPED MAPLE)
Cornus florida (FLOWERING DOGWOOD)
Hamamelis virginiana (WITCH-HAZEL)

Shrubs

Calycanthus fertilis (SWEET-SHRUB)
Clethra acuminata (PEPPER-BUSH)
Gaylussacia ursina (BEAR HUCKLEBERRY)
Hydrangea arborescens (HYDRANGEA)
Kalmia latifolia (MOUNTAIN LAUREL)
Lyonia ligustrina (LYONIA)
Pyrularia pubera (BUFFALO-NUT)
Rhododendron calendulaceum (FLAM AZALEA)
Rhododendron maximum (RHODODENDRON)
Vaccinium simulatum (HIGH-BUSH BLUEBERRY)

Woody Vines

Parthenocissus quinquefolia (VIRGINIA CREEPER)
Smilax rotundifolia (ROUND-LEAF CATBRIER)

Ferns

Dryopteris noveboracensis (NEW YORK FERN)
Polystichum acrostichoides (CHRISTMAS FERN)

III. OPEN OAK AND PINE STANDS

Plants of dry, rocky and exposed slopes and ridges.

Trees

Acer rubrum (RED MAPLE)
Amelanchier laevis (SERVICE BERRY)
Castanea dentata (CHESTNUT)
Nyssa sylvatica (BLACK GUM)
Oxydendrum arboreum (SOURWOOD)
Pinus pungens (TABLE MOUNTAIN PINE)
Pinus rigida (PITCH PINE
Pinus strobus (WHITE PINE)
Pinus virginiana (VIRGINIA PINE)
Quercus alba (WHITE OAK)
Quercus coccinea (SCARLET OAK)
Quercus prinus (CHESTNUT OAK)
Quercus velutina (BLACK OAK)
Quercus pseudoacacia (BLACK LOCUST)
Sassafras albidum (SASSAFRAS)

Tall Shrubs

Clethra acuminata (PEPPER-BUSH)
Kalmia latifolia (MOUNTAIN LAUREL)
Lyonia ligustrina (LYONIA)
Pieris floribunda (FETTER-BUSH)
Pyrularia pubera (BUFFALO-NUT)
Pyrus (Aronia) melanocarpa (BLACK CHOKEBERRY)
Rhododendron calendulaceum (FLAME AZALEA)
Rhododendron maximum (RHODODENDRON)
Smilax glauca (GIAUCOUS CATBRIER)
Smilax rotundifolia (ROUND-LEAF CATBRIER)
Vaccinium simulatium (HIGH-BUSH BLUEBERRY)
Vaccinum stamineum (BEERBERRY)

VITA

Carl Allinger Koch was born in Cincinnati, Ohio, on January 18, 1943. He was graduated from Western Hills High School, Cincinnati, Ohio, in 1961. He received an Associate Arts degree from the University College, University of Cincinnati, and a Bachelor of Arts degree in geology from the University of Cincinnati in June, 1968. He accepted a graduate assistantship at the University of Tennessee and received the Master of Science degree in geology in December, 1974.

Mr. Koch is married to the former Patricia Graves Harris of Knoxville, Tennessee.

LEGEND

DEBRIS SLIDE / FLOW TRACK SCARS
FLOOD MODIFED CHANNELES
● WATER BLOWOUT SCARS
× SOIL PITS
D-1 DRAW No.

PLATE I

WEBB MOUNTAIN STUDY AREA

N

(1969)

0 .25 .50 1
KILOMETER

0 .25 .50 1
MILE

CONTOUR INTERVAL 40 FEET

RICHARDSON COVE | JONES COVE

PLATE I

35°45'
83°15'